modern castings

AUGUST, 1958

The Foundrymen's Own Magazine

Titanium Castings p 18

A bright future is predicted for Ti in chemical and aircraft industries

CO_2 Stack Molding p 22

Shoot-gas-stack molds for high-speed profit cycles in the foundry

Spinning Castings p 26

King-size centrifugal castings require unusual installation at Sandusky Foundry

Core Oil Evaluation p 24

Prize winning paper tells how to evaluate core oils with four tests

future meetings and exhibits

AUGUST

7 . . AFS Executive Committee, *Special Meeting*. Dearborn Inn, Dearborn, Mich.

7-8 . . AFS Board of Directors, *Annual Meeting*. Dearborn Inn, Dearborn, Mich.

18-22 . . Illinois State Board of Vocational Education, *Foundry Workshop*. University of Illinois, Urbana, Ill. *Co-Sponsored by AFS*.

SEPTEMBER

7-12 . . American Chemical Society, *Fall Meeting*. Chicago.

10-11 . . American Die Casting Institute, *Annual Meeting*. Edgewater Beach Hotel, Chicago.

15-19 . . Instrument Society of America, *Instrument-Automation Conference & Exhibit*. Convention Hall, Philadelphia.

22-23 . . Steel Founders' Society of America, *Fall Meeting*. The Homestead, Hot Springs, Va.

22-24 . . Material Handling Institute, *Joint Industry Fall Meeting*. The Greenbrier, White Sulphur Springs, W. Va.

23-26 . . Association of Iron and Steel Engineers, *Exposition*. Public Auditorium, Cleveland.

29-Oct. 3 . . Association Technique de Fonderie de Belgique, *25th International Foundry Congress*. Brussels and Liege, Belgium.

OCTOBER

6-8 . . National Association of Corrosion Engineers, *Annual Meeting, Northeast Regional Division*. Somerset Hotel, Boston.

8-10 . . Gray Iron Founders' Society, *Annual Meeting*. Sheraton Park Hotel, Washington, D. C.

13-18 . . National Industrial Sand Association, *Semi-annual Meeting*. The Greenbrier, White Sulphur Springs, W. Va.

15-16 . . AFS *Michigan Regional Foundry Conference*. University of Michigan, Ann Arbor, Mich.

16-17 . . AFS *All Canadian Regional Foundry Conference*. Royal Connaught Hotel, Hamilton, Ont.

16-18 . . Foundry Equipment Manufacturers' Association, *Annual Meeting*. The Greenbrier, White Sulphur Springs, W. Va.

17-18 . . AFS *New England Regional Foundry Conference*. Massachusetts Institute of Technology, Cambridge, Mass.

18-21 . . Conveyor Equipment Manufacturers Association, *Annual Meeting*. The Greenbrier, White Sulphur Springs, W. Va.

20-24 . . National Association of Corrosion Engineers, South Central Region, *Conference & Exhibition*. Roosevelt Hotel, New Orleans.

22-23 . . National Management Association, Annual Meeting. Statler-Hilton Hotel, Los Angeles.

27-30 . . Metallurgical Society of American Institute of Mining, Metallurgical & Petroleum Engineers, *Fall Meeting*. Carter Hotel, Cleveland.

27-31 . . American Society for Metals, *National Metals Exposition & Congress*. Public Auditorium, Cleveland.

30-31 . . AFS *Purdue Metal Castings Conference*. Purdue University, West Lafayette, Ind.

31-Nov. 1 . . AFS *Northwest Regional Foundry Conference*. Multnomah Hotel, Portland, Ore.

NOVEMBER

10-12 . . Steel Founders' Society of America, 13*th Technical & Operating Conference*. Carter Hotel, Cleveland.

20-21 . . National Foundry Association, *Annual Meeting*. Drake Hotel, Chicago.

DECEMBER

3-5 . . American Institute of Mining, Metallurgical & Petroleum Engineers, *Electric Furnace Steel Conference*. Statler Hotel, Detroit.

3-5 . . National Association of Manufacturers, *Annual Meeting*. Waldorf-Astoria Hotel, New York.

9 . . Material Handling Institute, *Annual Meeting*. New York.

The company is giving her a gold watch. She hasn't missed a pay day in 25 years.

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vol. 34, no. 2

modern castings

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FOUNDRY FUTURE IS BRIGHT

Your foundry industry is faced with a growth as inevitable as birth and marriage. To prove it let's consider first what population growth can mean to the foundry business.

The Bureau of Census, with their usual cautiousness, predicts this country will have a population between 207 and 228 million people by 1975. We find, for instance, that there should be 14 million more people between the ages of 20 and 30 in 1975 than there were in 1955. A 66 per cent increase in 20 years! An additional one million extra people will be in the 30 to 40 age group, and as many as 33 extra millions less than 20 years old. In 1975 there should be nearly 50 million more people under 35 years of age than in 1955. Think of the effect in new purchases these people will have and what effect this will have on the foundry industry!

The 15 million additional people in 20 to 34 age class will be 15 million extra *heavy* consumers of foundry products. This is the age span when people marry, travel, buy automobiles, homes, appliances—make the heavy purchases of their lives. If but one automobile is sold per year to every five of these people, it would mean three million automobiles, or a 50 per cent increment to present production rate.

Supplementing population growth as a factor affecting business is the tremendous increase in standards of living. This step-up in personal prosperity was made possible by our embracement of scientific research as a mode for economic and social progress. And it resulted in mechanization and increased productivity of our industry and agriculture. Since 1929 the nation's productivity has increased from 163 billion to 435 billion dollars on basis of current dollars in each case. A projection of this rate of increase would indicate that we reach a gross national product of 870 billion dollars in 1975—or exactly twice 1957 value.

The present per capita consumption of steel per year is about 1150 lb; of copper, 29 lb; aluminum, 20 lb; zinc, 14 lb. How, you might ask, will Americans manage to consume twice as much metal in 1975?

Increased standards of living cause people to consume indirectly much metal that they never see. The metal to build factories to produce a variety of goods; the metal for machinery, power plants and transmission lines; for roads, bridges, ships, freight cars and aircraft—this is where the bulk of per capita consumption goes. And as our society gets more complex, it takes more "behind-the-scenes" metal to support the needs of each of us. All great technological promises of the moment, such as atomic energy, supersonic flight and automation represent huge "behind-the-scenes" metalcasting consumers.

Population growth, productivity increase, standard of living rise and technological advances will all contribute to a bright future for the foundry industry.

Dr. C. E. Williams,
President, Clyde Williams & Co., Columbus, O.

■ *Excerpted from a talk presented by Clyde Williams at Foundry Educational Foundation 11th Annual College–Industry Conference.*

obituaries

J. T. Osler, 73 retired board chairman, Continental Foundry & Machine Co., East Chicago, Ind., died July 4.

J. T. Osler

Dr. Vsevolod N. Krivobok, 65, a well-known authority on stainless steels and supervisor of the Stainless Steel and Heat-Resistant Alloy Section of the Development and Research Div., International Nickel Co., New York, died after a brief illness. Born in Poltava, Russia, Dr. Krivobok was a naturalized citizen of the United States. Prior to joining International Nickel in 1944, Krivobok had been director of research and chief metallurgist of Lockheed Aircraft Corp., Burbank, Calif. He was a member of the faculty and Professor of Metallurgy, Carnegie Institute of Technology, Pittsburgh, Pa., 1924-1940, while also serving as Associate Research Director for Allegheny Ludlum Steel Corp., Brackenridge, Pa.

Dr. Krivobok was a member of the Metallurgical Research Bureau, Carnegie Institute of Technology; Campbell Memorial Lecturer for American Society for Metals and presented the Sauveur Memorial Lectures in 1939 and 1943. He was also chairman of the High Alloys Committee of the Welding Research Council; a retired trustee of the American Society of Metals; and a member of the American Institute of Mining, Metallurgical, and Petroleum Engineers, American Society for Testing Materials, American Welding Society, British Iron and Steel Institute, and the British Institute of Metals.

C. R. Lamphier, assistant core superintendent, Gale Mfg. Co., Albion, Mich., died May 11. He was a member, AFS Central Michigan Chapter.

V. Delport, 32-Year AFS European Delegate, Dies

■ Vincent Delport, 69, having recently resigned after 32 years as AFS delegate to the International Committee of Foundry Technical Associations, died at his home in Surrey, England, June 3.

Vincent Delport

He was past president, and treasurer since 1956, of this remarkable organization comprising the technical foundry groups of 17 countries, and recording free interchange of technical data and information unique among international associations.

At the time of his death he served as director and treasurer, Penton Publishing Co., Ltd., Westminster, London, England.

Last year, he was honored with an AFS Service Citation, "For distinguished service to the Society as its European Representative, especially in connection with the International Foundry Congresses."

A past president of the London Chapter, Institute of British Foundrymen, Delport was recently recognized for his long, devoted service to I.B.F. and the International Committee through presentation of the institute's Meritorious Service Medal.

He was awarded the Gold Medal of the Association Technique de Fonderie, in 1938.

Born in London, Delport graduated in metallurgy from the Ecole Centrale des Arts et Manufacture in 1913. He spoke fluent French, serving with the French army during World War I, the French Military Mission to the United States in 1917 and with the French High Commissioner in Washington in 1918; after which he joined the staff of the United States Steel Products Co.

Combining the talents of linguist and diplomat with a broad knowledge of metallurgy and industry, Vincent Delport served AFS well as "ambassador without portfolio."

Circle No. 405, Page 7-8

Build an idea file for plant improvements. The post-free cards on page 7-8 will bring more information on these new . . .

products and processes

HEAT REFLECTIVE CLOTHING . . . made of a new asbestos fabric features greater wear resistance, according to manufacturer, 168 per cent longer than clothing made of regular asbestos fabric. Said to provide greater protection against splash and heat transmission, and to reflect 40 per cent of radiant heat. Complete line offered. *Raybestos-Manhattan, Inc.*

For Manufacturer's Information Circle No. 445, Page 7-8

LOW LIFT TRUCK . . . built to handle either pallets or skids. Auxiliary platform folds back and remains upright so that operator-led truck can move pallets. Platform can be lowered over pallet forks, converting to platform or skid handler. Available in lowered heights of 6-11 in. *Automatic Transportation Co.*

For Manufacturer's Information Circle No. 446, Page 7-8

CERAMICS ENGINEERING . . . applied to foundry industry is subject of new process available to licensees. Cement and magneto chemistry is involved. Company officials state that the licensee is taught sufficient chemistry to select properly from the thousands of available materials. *Coldhard-HiUtek Div., United States Trading & Service Corp.*

For Manufacturer's Information Circle No. 447, Page 7-8

SAND CONDITIONING . . . machine reportedly picks up sand continuously from foundry floor, cleaning, preparing and aerating it for reuse. Unit uses centrifugal force elevator which manufacturer claims takes no floor space from sand preparation components, allowing capacity up to a ton of sand per min to be prepared in small, self-propelled unit. Officials state that mold production increases and savings result from reduced need for special facings, metal salvage and reduced space usage. *States Engineering Corp.*

For Manufacturer's Information Circle No. 448, Page 7-8

CERAMIC COATINGS . . . for machinery, structural components and fixtures provide protection against high temperatures, corrosion shock, abrasion and fatigue. Manufacturer claims tests have shown some coated metal samples have fatigue life ten times longer than uncoated. Said to permit "low grade" metals and alloys to give much greater performance than the expensive untreated "high grade" materials. *Bettinger Corp.*

For Manufacturer's Information Circle No. 449, Page 7-8

MOLD WALL DEFLECTION . . . of shell specimens measured with testing accessory for specimens heated up to 2000 F. Measures mold wall movement in units of 0.0001-in. under static load range, 0.25-4 lb. Includes furnace, pyrometer, powerstat for temperature control and specimen support. *Harry W. Dietert Co.*

For Manufacturer's Information Circle No. 450, Page 7-8

SURFACE INSPECTION . . . by spray-can dye method utilizing nontoxic materials. Cleaners and developers made with chlorinated hydrocarbons. Oil-base penetrants have chlorine-free formulations. New product reportedly can be used for testing under conditions previously considered a fire hazard. *Magnaflux Corp.*

For Manufacturer's Information Circle No. 451, Page 7-8

SELF-DUMPING HOPPER . . . designed for corrosion-resistant service features stainless steel liner said to resist corrosion of hot, cold, wet or dry materials. Hopper automatically dumped by releasing latch, after

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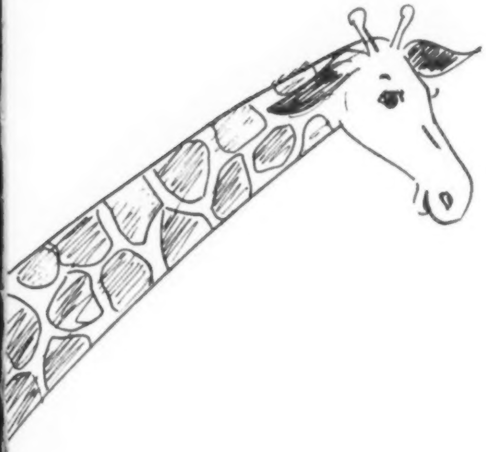

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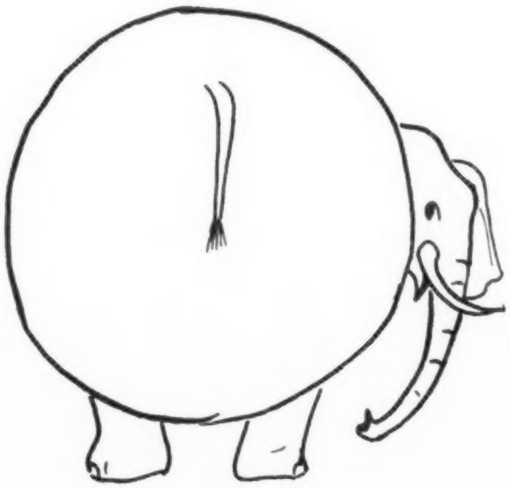

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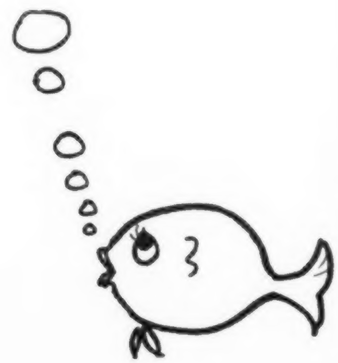

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which it rights itself and locks into position. Casters provide easy movement. Five sizes, 1/2 to 2 yard capacities. *Apex Welding & Fabricating Corp.*

For Manufacturer's Information Circle No. 452, Page 7-8

SHAKEOUT . . . reported to achieve faster movement of flasks and sand molds from casting machine. Six degree starter deck speeds flasks or molds onto main deck, which slopes three degrees. Vibrating shakeout accommodates 24 x 20-in. flasks. *Allis-Chalmers Mfg. Co.*

For Manufacturer's Information Circle No. 453, Page 7-8

CAR BOTTOM FURNACE . . . needs neither pits nor rails below floor level. Car is motor driven by rack and pinion to run car in and out of furnace. Heating elements mounted on side and back walls, and door of car. Time switch changes electrical connections to elements from Delta to Star to adjust to demand characteristics of foundry operation. Fan in roof of furnace provides circulation at lower temperatures (designed for 1800 F). Dimensions, 3x3x6 ft. *Waltz Furnace Co.*

For Manufacturer's Information Circle No. 454, Page 7-8

DRUM LIFT . . . attachment for fork lift trucks or hoists makes drum lifting one-man operation. Designed not

to mar drums, equipped with safety cable release. Capacity, 2000 lb. *Ladd Drum Lifter & Equipment.*

For Manufacturer's Information Circle No. 455, Page 7-8

HEAVY-DUTY CYLINDERS . . . air and hydraulic, designed for use on automated equipment. Pressure ratings of 200 psi (air) and 1000 psi (hydraulic). Offered in sizes, 1-1/2 to 8-in. bores, and five mounting styles. *S-P Mfg. Corp.*

For Manufacturer's Information Circle No. 456, Page 7-8

VERTICAL LIFTER-DUMPER . . . can lift by skip-hoist 2500 lb to any practical height, dumping load at prescribed angle of 45 deg. Push-button

operation for "up," "down" or "stop" operation puts operator in complete control. Complete dumping cycle can be made automatically. Company will custom design dumper to individual needs to lift and dump all types of containers and any free-flowing material. *Essex Conveyors, Inc.*

For Manufacturer's Information
Circle No. 457, Page 7-8

BARREL FINISHING . . . machine with barrel capacity of 13.8 cu ft or 1000 lb. Can be divided into two compartments. Adjustable speed from 10 to 30 rpm. Offered either un-

lined or with Neoprene lining. Adequate clearance provided under barrel for dumping the finished castings into containers. *ALMCO, Queen Products, Inc.*

For Manufacturer's Information
Circle No. 458, Page 7-8

CARBURIZING - NITRIDING FURNACE . . . gas-fired, designed for precision control of both atmosphere and temperature, is also useful for all types of general heat-treating work up to 1850 F. Unit is said to provide fast heat recovery, atmosphere-tight seal and efficient operation. Available also in a number of standard-size electric models. *Pacific Scientific Co.*

For Manufacturer's Information
Circle No. 459, Page 7-8

FLOW INDICATOR . . . for use wherever there is circulating water or oil, indicates at a glance whether flow is taking place. Spinning ring under toughened glass dome said to be clearly visible even in bad light. Foundry applications include water-cooled die-casting machines, cupolas, air compressors; and lubricating oil to machine tools. Available for flows 0.075-120 gpm in pipe sizes to 3 in. *McIntosh Equipment Corp., Walker Crosweller Div.*

For Manufacturer's Information
Circle No. 460, Page 7-8

MOLDING PRESS . . . 75-ton down-acting, hydraulic model offers controlled speed approach with stepless tonnage adjustment from 5-75 tons. Designed for economical operation on shop air line. Installation reportedly quick and inexpensive. Features electrical or steam-heated

platens with multiple platen arrangements. Working area, 13x13 in., 12-in. stroke. *Allied Engineering & Production Corp.*

For Manufacturer's Information Circle No. 461, Page 7-8

PREHEATED CUPOLA AIR . . . with fired heaters said to make initial melt faster and give hotter iron while cutting cupola coke consumption 20-30 per cent. Furnished with burners and all necessary controls. Delivers air at 1000 F in 2-3 min. *Brown Fintube Development Co.*

For Manufacturer's Information Circle No. 462, Page 7-8

VIBRATING FEEDER . . . is said to handle effectively foundry materials from heavy, sticky substances to light, dry foundry sand. Motorized, counterweight feeder will feed direct from hopper or bin at a uniform rate. Manufacturer states that unit handles hot materials as well as abrasives, eliminating leakage and spilling. Reportedly can be installed in almost inaccessible locations. Available in standard widths of 2, 3 and 4 ft; lengths, 5-8 ft. Capacities to 250 tons per hr. *Link-Belt Co.*

For Manufacturer's Information Circle No. 463, Page 7-8

ELECTRONIC RECORDING . . . instrument for precise measurement of pressure, force, tension and weight. Foundry applications include recording weight of scrap charge for foundry furnace and weight of contents in storage tanks. *Leeds & Northrup Co.*

For Manufacturer's Information Circle No. 464, Page 7-8

SEIF-CLEANING BUCKET . . . mounted on chain attachments is reported to efficiently elevate tempered foundry sand with complete discharge of material. Individual design said to assure proper stripper-plate movement. Chain mounted buckets an addition to company's self-cleaning belt mounted buckets. All sizes available. *Pekay Machine & Engineering Co.*

For Manufacturer's Information Circle No. 465, Page 7-8

TEMPERATURE MEASUREMENT . . . of any solid, liquid or luminous

"Why are so many PROTECTIVE features engineered into the new H-25 PAYLOADER?"

This question is frequently asked of Ralph Beyerstedt, Executive Vice President of The Frank G. Hough Co. because of his more than twenty years of experience in charge of engineering.

"During the development of the H-25," Mr. Beyerstedt explained, "as soon as it became evident that we were going to obtain the increased capacity, production, ease of operation, speed and mobility we sought, our engineers then gave major attention to protective features for operational insurance against wear, maintenance, abuse, downtime and the like.

"The more than 10,000 small HA 'PAYLOADER' tractor-shovels that we have produced for steel mills, foundries and chemical and fertilizer plants operate under conditions which continuously subject the machines to dust, dirt, powder and foreign materials.

"Because these are sources of major headaches for owners and operators," said Mr. Beyerstedt, "we have given extra special consideration to elimination of the problems they cause."

Dozens of Protective Features

"Starting with the *triple* air cleaning system (1) we have provided a precleaner and dual oil-bath air cleaners for engine intake, and crankcase breather tube (17).

"Next, each of the three oil systems is equipped with a cartridge-type oil filter (2). These take care of the engine oil, the hydraulic-system oil, the power-shift transmission and torque-converter oil.

"The self-adjusting, hydraulic service brakes (3) are *sealed* and the parking brake is enclosed in the transmission, operates in oil for greater dependability.

"The reservoir (4) of the closed, pressure-controlled hydraulic system has built-in cartridge-type filter and *sealed* dip-stick."

In discussing the components of the electrical system, Mr. Beyerstedt said, "There is a 12-volt system with the battery grounded direct to the starter housing; a non-vented, *sealed* generator (5); *sealed* ignition distributor (6); shock-mounted instrument panel (7) with solder-coated terminals and a plastic-coated wiring harness (8); *sealed* circuit breaker together with *sealed* ignition and starter switches (9) plus clutch-pressure warning device (18).

"*Sealed* teflon bushings are used extensively throughout with brake and transmission disconnect mechanism (10) and valve control mechanism (11).

"These *sealed* ball joints (12) are used with gearshift linkage and *sealed* ball joints of a different size (13) are used with the accelerator linkage.

"The steering linkage uses *sealed* ball joints on the tie rods (14), and on the drag link (19). The steering bell crank (15) is *sealed*, also the spindle and kingpin assemblies.

"The boom arm mechanism has tapered roller bearings and dust covers on the bell cranks (16) and *sealed* mated bronze and steel bushings plus O-ring seals at all major pivot points."

Now, What About Production?

The carry capacity of the H-25 "PAYLOADER" is 2,500 lbs.—25% greater than has ever before been available in a tractor-shovel of its size and maneuverability, yet it easily loads and unloads box cars with narrow 6-foot doors. It is the only loader in its size range with *complete* power shift transmission—having 2 speed ranges forward and two in reverse. Power-steer is also standard so that operating speed and handling ease favors all-out production all day without operator fatigue.

Other plus features of the H-25 that mean more production, less maintenance and longer life are the exclusive power-transfer differential, wet-sleeve overhead valve engine, full-shift fuel capacity, 4,500 lbs. of bucket breakout force and 40° bucket tip-back at ground level.

Your "PAYLOADER" Distributor wants to show you how the greater capacity, speed and handling ease of the H-25 can cut your bulk-handling costs. Ask him about Hough Purchase and Lease Plans, too. The Frank G. Hough Co., 711 Sunnyside Ave., Libertyville, Ill.

8-A-1

The H-25 "PAYLOADER" is effectively shielded against dust, dirt and foreign materials.

flame in the 1500-4000 F range without need for making emissivity corrections, manufacturer claims. Instrument designed to measure temperature of flowing molten metals or of moving objects in a furnace rather than the furnace temperature.

Radiation-ratio pyrometer consists of two units, a sensing head for detecting radiation, and a control unit which interprets the information. *Shaw Instrument Corp.*

Circle No. 466, Page 7-8

THREE-WHEELED FORK TRUCK . . . gas powered, features a clutch unconditionally guaranteed for 12 months. New clutch offers lurch-free

operation and five times longer clutch life. Five basic models, capacities 1500-3000 lb. *Mercury Mfg. Co.*

Circle No. 467, Page 7-8

AIR PRESSURE LOSS . . . reduced in compressed air systems, by poppet valves which open and shut from 2000 to 25,000 cycles per min in direct ratio to the pressure drop. This reduction of the line pressure loss reportedly offers up to 80 per cent more energy for foundry operations which are useing compressed air. *L. C. Nesham Products.*

Circle No. 468, Page 7-8

RADIATION PYROMETER . . . gives 98 per cent of full reading in two seconds. Special unit for moving objects gives reading in 0.6 sec. Measures radiant energy given off by hot objects. Can be used at greater distance from hot objects than is possible with the other types. Models cover temperatures 1000-3300 F. *Instrument Div., Robertshaw-Fulton Controls Co.*

Circle No. 469, Page 7-8

METAL PROTECTING . . . coating of wax for protection of metal parts against atmospheric conditions and handling. Manufacturer reports that,

Circle No. 410, Page 7-8

unlike present metal protectors, it is not oily or greasy and contains no resin or shellac, but combines protection with lubrication while enhancing appearance. Manufacturer claims material to dry tack free in 20-30 min at room temperature. *S. C. Johnson & Son, Inc.*

Circle No. 470, Page 7-8

HYDRAULIC TRIM PRESS . . . for trimming castings, swaging, stamping, blanking, drawing, shearing, etc. Features high-speed ram, up to 1300 in.-per-min. Shut height and position and length of stroke can be rapidly adjusted by means of set collars. If casting is cocked, press will not reach power stroke. Designed to be easily moved with lift truck. This model, 25-ton press with stroke adjustable from 0 to 1300 in. per min. *B & T Machinery Co.*

Circle No. 471, Page 7-8

HEAVY-DUTY TESTING . . . machine designed for Rockwell testing of long, heavy or bulky castings, dies, and shafts without resorting to portable testers. Large table, 40 x 10 in., provided which is raised evenly against indenter by hand-wheel drive. Handles loads up to 550 lb and accommodates work up to 27 in. below the indenter. Machine is manufactured in West Germany. *Opto-Metric Tools, Inc.*

Circle No. 472, Page 7-8

SAND STRENGTH . . . machine designed to handle testing requirements on all materials in foundry use. Manufacturer claims machine offers great sensitivity, range and versatility in measuring the green and dry compressive, tensile and shear strengths. Accessories available for measuring and recording deformation or deflection values of various molding, core and shell sands used in foundries. *Harry W. Dietert Co.*

Circle No. 473, Page 7-8

WOOD FLOUR . . . for use in sand molds and cores. Birchwood flour, said by manufacturer to be refined to exceptionally high purity and uniformity, compensates for expansion, provides reducing atmosphere, aids sand flow around patterns, improves collapsibility, bonding and porosity. Flour is available in all mesh sizes and with desired moisture content. Testing samples will be sent on your request. *Wilner Wood Refinery.*

Circle No. 474, Page 7-8

INSPECTION LIGHTS . . . designed for use in industrial inspection equipment. Produce clear beam of light said to be free of filament shadows found in lights using flashlight lamps. Equipment designed for inspecting

cavities in castings which could not otherwise be inspected visually. Available with extension shafts, rotatable mirrors, magnifying lenses, and directional caps. Self-contained power source. *Welch Allyn, Inc.*

Circle No. 475, Page 7-8

PLATFORM TRUCK . . . features clutching and shifting, said to reduce driver fatigue and maintenance to a minimum. Flat bed measures 78 in.

behind engine enclosure, with space at right of engine for handling bar stock, pipe, lumber, etc. Capacity, 4000 lb. *Prime-Mover Co.*

Circle No. 476, Page 7-8

MANUAL LIFT AND TILT . . . of steel drums and transporting over rough surfaces said to be accomplished with ease. The manufacturer claims pneumatic tires and telescopic lifting provide unmatched versatility. *Big Joe Mfg. Co.*

Circle No. 477, Page 7-8

INTERIOR HARDNESS TESTING . . . of engine blocks, castings, etc. with new portable tester for accurate Brinell readings for hitherto inaccessible spots, manufacturer claims. Instruments available for openings with minimum diameter of six in. for tests at a depth of 10 in. or more. *King Tester Corp.*

Circle No. 478, Page 7-8

VERSATILE FINISHING . . . of castings, as well as grinding and deburring operations, possible with what manufacturer claims is a "seven in one" machine. Bench-type machine incorporates a cutting abrasive belt and a serrated contact wheel, with coated abrasive disc fastened to side of contact wheel, and tilting adjustable table permitting square and angle grinding as well as chamfering and surfacing.

Abrasive belt extension arms available for roughing and finishing operations at the same time. Inside diameter finishing accomplished with coated abrasive sleeve on expanding rubber drum. Grinding wheels and wire brushes may be mounted and operated at either end of the motor. *Curtis Machine Div., Carborundum Co.*

Circle No. 479, Page 7-8

the editor's field report

by *Jack Schaum*

■ In case you are trying to prognosticate about the economic future you should enjoy this excerpt from a recent Chicago Tribune editorial titled the Lowdown on the Slowdown. . . . "it should be noted that a slowing up of the slowdown is not as good as an upturn in the downcurve, but it is a good deal better than either a speedup of the slowdown or a deepening of the down curve. . . . a definite unemployment decrease in the rate of increase clearly shows that there is a letting up of the letdown." After all this gobbledygook, let's go fishing.

■ Improved heat conductivity for epoxy resins has long been the goal of the manufacturers and a need of the foundry industry. Epoxy patterns get hot and stay hot when contacting hot molding sands; ergo, sand starts to stick to pattern. Epoxy dies for wax injection by investment casters conduct the heat away from the molten wax too slowly. Higher conductivity might even permit epoxy patterns to be used for shell molding. A prominent resin formulator has come up with a partial solution to the problem that shows promise. Steel fibers are given the optimum directional orientation for heat flow away from pattern surface by applying a magnetic field. With the fibers standing on end, liquid epoxy is poured around them. Fibers are locked in position by hardening resin. It is claimed that the resulting material has a heat conductivity equal to 304 stainless steel!

It might surprise you to learn that more magnesium goes into castings than into wrought products. In 1957, 15,166 tons of magnesium castings were shipped compared with 10,959 tons in wrought form. The casting total comprises 7494 tons of sand castings, 885 tons of permanent mold castings and 2047 tons of die castings.

U. S. Pipe & Foundry Co., Chattanooga, does not have the problem of sodium silicate bonded cores sticking to core boxes nor the silicate building up in the box. Problem solution lies in the use of a rubber-base plastic coating instead of shellac. Moisture in CO_2 sand will soften shellac but the plastic coating seals surface of core box against moisture. For release of core and to prevent build up, silicone is applied to core box about once a day.

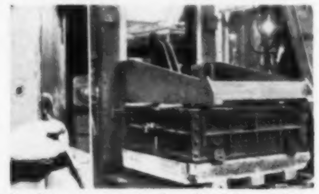
The AFS Malleable Iron Division has set out on an ambitious research project:—to develop techniques for producing heavy-sectioned malleable iron with casting sections in excess of 6 in. thick. Success in this program would give the malleable iron industry a real boost. Malleable applications could be broadened to include many cast shapes heretofore too heavy in cross section to solidify as white iron.

Circle No. 413, Page 7-8

product report

Lubrication

. . . was such a problem for D. J. Murray Mfg. Co., Wausau, Wis., that the slides of the foundry roll-over machine, "soon became scored and rough to a point where it caused much vibration while in motion." Problem was solved by the use of a colloidal graphite dispersion. "dag 35," manufactured by Acheson Colloids Co., Port Huron, Mich., was applied in a thin coat on the roll-over slides daily. Previous lubrication with dry graphite and rosin had both resulted in scoring.



Applying a coat of colloidal graphite lubrication to giant roll-over machine.

The colloidal graphite dispersion markedly improved machine operation. Company officials report that small scratches have all but disappeared, and larger and deeper scores are filling up. One application of the lubricant is sufficient for 90 roll-overs, an average day's operation. Sixty tons of material are handled in eight hr day.

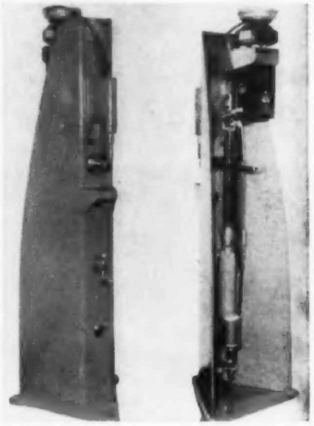
The company has been using the lubricant on the roll-over machine for nearly two years and has reportedly made no repairs on it and are not expecting to make any for another two years.

According to a company spokesman, "the slides would have to have been replaced after six months of operation if we hadn't started using 'dag 35.' They are in better condition now than they were after two months of use with the old method of lubrication."

Automatic stud driving

. . . machine for fixing studs in die castings uses the stud as its own tap. Studrive units, which were developed by Studrive, Inc., Detroit, may be grouped about a single fixture to form a special machine capable of automatically placing as many as eight studs in blind holes in a casting. Company officials state this operation is accomplished in less than one

second; and that when a production run of a particular casting is completed, the units may be regrouped to handle a completely different casting. Studs may be driven within two-in. centers of one another.



Vibratory hopper, top, supplies studs at pneumatic-actuated driving head.

Studrive officials report that their machine forces the stud into the casting in timed relation to its rotation; the stud being used as a tap to cut its own threads. If the problem should arise, configuration of the units are said to allow grouping of eight units with one another so as to drive studs around the points of a one-in. radius circle. The company claims the units to be adaptable for driving studs in any casting in which all studs are parallel to one another.

To join the units together, it is only necessary to mate the locating bosses and holes provided on each unit. Bosses may be bolted to the floor. Units are pneumatically driven from a standard 80 psi line; installation is complete when air connections are made to each machine and a master valve.

Vacuum sintering system

. . . installed with novel arrangement of pumps and furnaces provides unusual operating advantages for Wah Chang Corp., Glen Cove, N. Y. The system, set up by Rochester Div., Consolidated Electrodynamics Corp., Pasadena, Calif., includes two 300-lb capacity sintering induction furnaces served by four vapor diffusion (KS-2000) pumps and two Heraeus Roots pumps, and maintains a constant low pressure throughout the process despite large bursts of gas periodically given off by charges in the furnaces. The vapor pumps are connected to furnaces for evacuation. Roots pumps are mounted between and connected to both furnaces; valving results in efficient cycling in both furnaces.

Titanium Castings . . .
IS THE TIME RIPE?

New markets can lift titanium castings from severe depression to new expansion

JOHN H. GARRET
Chief, Materials Division, and

FRANKLIN P. HUDDLE
Conservation Specialist Office of Assistant Secretary of Defense Research and Engineering

How It's Done

Vacuum furnace is essential to production of titanium castings. Melting capacity of this skull-type furnace is 50 pounds.

The growing pains of the titanium industry have been replaced by the agony of a severe depression. Expansion plans have been dropped, production has been curtailed, competing companies have merged, and future prospects have darkened. The present operating rate in the titanium industry is a much smaller percentage of capacity than in the steel industry. Two of the government-sponsored titanium plants have ceased operation. In the face of all these ailments, the industry has a good chance to recover its fortunes by developing a substantial additional market for titanium castings.

The history of titanium as an industrial material of consequence began shortly after the close of World War II. Perfection of the Kroll reduction process coincided with the early encounter by aircraft engineers with aerodynamic heating achieved with turbo-jet powered aircraft at supersonic speeds. Inability of aluminum alloys to withstand the moderately elevated temperatures of high speed flight made necessary the development of a light metal that could serve in this assignment. Titanium was universally acclaimed as the most promising candidate. Indeed, it went from amateur status to "middleweight champion" before it had even entered the ring.

There is a popular misconception that in some way titanium's realized properties have fallen short of the advance publicity. For example, an article in *Time Magazine*, issue of Sept. 16, 1957, titled "Fiasco in Titanium?", quoted one producer as saying that the metal was the "greatest fiasco in history." ("It draws gases to it like flies to flypaper; the cost is forbiddingly high; and the strength-to-weight ratio is not everything it's cracked up to be.")

The fact of the matter is that titanium has gratified the highest expectations of the technical people in the Department of Defense, and among its contractors. The titanium alloys available today are far better in quality, and rather lower in price, than the titanium metal on the basis of which the forecast of 35,000 tons of annual consumption was calculated some five years ago.

Moreover, the outlook for the wrought forms of the metal is today still exceedingly promising. There is a whole new generation of excellent sheet alloys. They are being developed under the Department of Defense sheet rolling pro-

gram—nearly ready for release to commercial production. An even better set of alloys, with higher strengths and other improved properties, is under development for the next succeeding generation. But despite this gratifying physical improvement in performance, titanium has not lived up to our expectations. It has not achieved the level of usefulness expected of it.

It is germane to ask why. After all, other new metals are coming along whose future success will depend on the wisdom with which we guide their development and application. What went wrong with titanium?

The Titanium Slump

There are four principal causes of the slump in titanium usage. It will be helpful to enumerate these in order to have a realistic understanding of the situation and prospects of the metal. And bear in mind, the future prospect for titanium, we firmly believe, is still good.

The most important cause of the titanium cut-back was a drastic reduction in the sheer numbers of aircraft being procured by the military services. This cut-back, attributable to rapid advances in missile technology, increased unit costs of high performance aircraft, and extreme pressure for economy exerted on the military services, inescapably meant reduced demand for titanium. After all, aircraft were and still are the principal outlet for the metal. It may be of interest that missile manufacturers are beginning to find the new high-performance titanium alloys of interest, however. For example, a component of one missile weighs 125 lb. in steel, 80 lb. in aluminum and 50 lb. in titanium alloy (6 Al-4 V).

A second cause was the rapid and unforeseen development of high strength steels suitable for aircraft applications. (A plausible case could be made for the proposition that development of high performance, precipitation-hardening stainless steels was the direct consequence and a legitimate by-product of the government titanium program.)

A third cause was the emergence of price as a major deterrent to the general use of titanium. While sponge prices moved steadily and impressively downward, spurred by reductions in the prices of high grade ore and process economies in the reduction plants, mill product prices were discouragingly steady. Anxiety of Air Force policy-making officials to hold costs of aircraft procurement within budgets led the service to reconsider some previously-approved applications of titanium.

A fourth principal cause for the drop in titanium usage is tied in with the trend toward welded and brazed honeycomb sandwich construction for aircraft. The commercially available titanium alloys are not yet as satisfactory as steel for this type of construction. Some of the newer alloys should help overcome this handicap. But during the period of this technological lag, aircraft designers have of necessity turned to steel to provide their requirements of structural strength plus fabricability.

Casting Opportunities

As a consequence of these four developments, the capacity of industry to produce titanium sponge and shapes is greatly in excess of current demand for the metal. But a time of travail like this can also be a time of opportunity. It is our conviction that there are now sound and more compelling reasons for taking a careful look at the possibilities inherent in titanium castings, not only for aircraft use but also for many and extensive corrosion-resistant applications.

The principle behind the casting industry is that a material is easier to shape as a liquid than as a solid. The principle behind rolling, extrusion and other methods of power-shaping, is that deformation enhances strength. Quite apart from the inherent difficulties of casting a reactive metal, there has not been much incentive to develop a titanium casting industry. The more attractive property of the metal from the outset was its combination of lightness with strength. This focused attention on its application in aircraft. Development of titanium was logically concentrated on wrought forms in which this prime property could be intensified and fully expoited.

Comparatively little attention was given to the technology of casting titanium. Not only did casting pose awkward technical difficulties; the high cost of the metal, lowered strength of the cast product, uncertain quality of castings, high mold cost and high scrap loss (in conventional casting practice) all offered serious obstacles. The only off-setting improvement in performance to be gained by overcoming all these obstacles was in corrosion resistance. It is understandable indeed that the casting

U. S. TITANIUM PRODUCTION AND CONSUMPTION*
(in short tons)

	Sponge Capacity	Sponge Production	Mill Products Shipped
1953	N.a.	2241	1114
1954	N.a.	5370	1294
1955	16,000	7398	1897
1956	24,000	14,595	5175
1957	27,700	17,263	5458

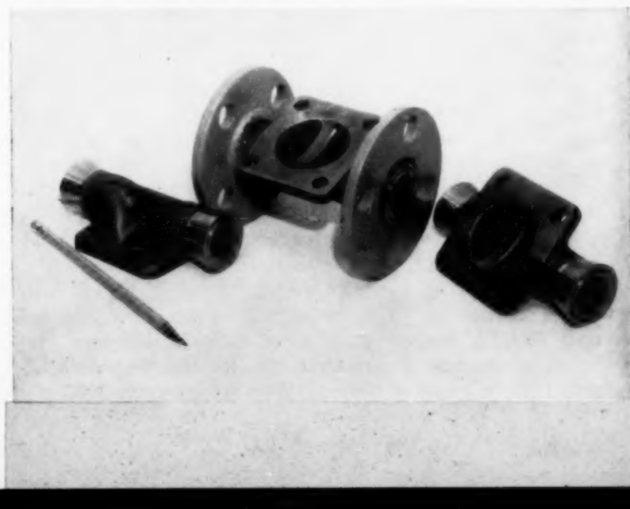
*Source: "General Review of the Titanium Metal Industry" (MAB-47-SM), Staff Study by Paul Tyler, 2/14/58

What It Costs

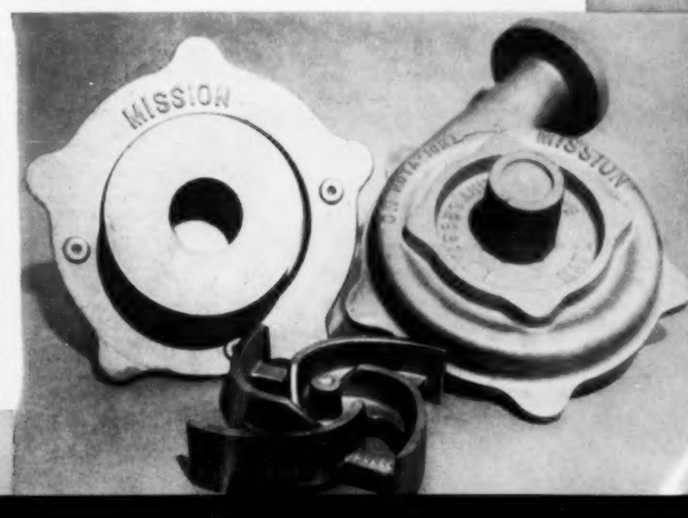
Prices listed for the castings below were quoted to Marquardt Aircraft Co. by Oregon Metallurgical Corp. Parts are now in use in a ram-jet engine. Titanium castings for civilian use are also nearing competitive pricing levels.

Oregon Metallurgical Corp. has produced a 5-in. OD x 4-in. ID x 6-in. long paper mill shaft sleeve with hardness over 300 BHN for $127. In stainless steel, part costs $120.00.

Diaphragm valve weight, 1-1/4 lb
Unit price for 25 units: $37.50*
Unit price for 50 units: $35.00*
Unit price for 100 units: $31.25*
*Prices based on casting weight of 1-1/4 lb



Centrifugal pump, 3 parts total weight, 53-1/2 lb
Unit price for 25 units: $802.50*
Unit price for 50 units: $749.00*
Unit price for 100 units: $642.00*
*Prices based on total weight of 53-1/2 lb



Titanium Castings for Chemical Industry

5-in. valve assembly weighs 160 lb.

Pump impeller has 5-in. diameter.

Centrifugal pump component parts.

Pump impeller resists corrosion.

OREGON METALLURGICAL CORP. PHOTOS

industry did not eye titanium with the same enthusiasm that inspired the aircraft industry and its suppliers. There have been a few isolated government programs in the development of titanium casting capability, and several private company programs. But by and large, there has been no substantial effort comparable with that directed toward wrought products. In short, titanium casting constitutes a major technological lag.

Lag in Casting

It is time to inquire whether this lag is warranted by circumstances; to determine what obstacles stand in the way of a full-fledged casting program in titanium; and to define appropriate measures of overcoming these obstacles.

To begin with, titanium in cast form is a lot more attractive than it was ten years ago. When properly alloyed, the metal offers strength levels comparable to the best cast steels. It yields a 40 per cent dividend in weight. Corrosion resistance of titanium far outstrips that of the best steels in many extreme environments. Cost influences are coming to bear on titanium to make it more nearly competitive with less noble metals. The literature abounds with instances in which titanium has successfully replaced other materials costing one-third as much, or less, and by outlasting them by factors of 10 or 100 has saved the user many times the added initial cost of the titanium.

Examples of successful application of titanium in corrosive environments were recently presented to the National Association of Corrosion Engineers at the March Meeting in San Francisco, by A. G. Caterson of Rem-Cru. Applications included equipment for Freeport Sulphur Company's Cuban nickel plant to handle a "corrosive and erosive slurry of dilute sulphuric acid with metallic ions," a titanium impeller exposed to "10 per cent sulphuric acid solution at 600 psi pressure and 400 F.," an impeller in a "solution of organic chlorides containing 3-1/2 per cent hydrochloric acid at 125 F.," a heat exchanger handling "a 15 per cent solution of sodium hypochlorite," a 'top hat' condenser "operating in 60 per cent nitric acid at 480 F and 300 psi pressure," plates in a calcium hypochlorite filter press, pumps and coils to handle ferric chloride, and a number of others.

Caterson, whose paper will shortly appear in *Corrosion Magazine*, presents a number of specific cost analyses to demonstrate that selection of titanium at higher first cost can often pay for itself rather quickly in terms of greatly improved life or reduced maintenance in corrosive environments.

Other savings were found in decreased wall thickness, elimination of the need for standby equipment and security from contamination of a costly chemical product. He concludes that because such corrosion analysis takes time, "we believe that now is the acceptable hour to begin evaluation of titanium equipment" in chemical, food, petroleum, and marine applications where corrosion is a problem.

Similarity to Magnesium

Then too, there is reason for preserving and strengthening our titanium industry. Like magnesium, titanium is one of the truly inexhaustible materials in the earth's crust. We have hardly scratched the surface, yet we have found reserves of high grade titanium ore sufficient to last us for decades. One established conservation principle in the Department of Defense is that we should strive to put to best use every elemental atom at our disposal. It follows that the ability to exploit a new abundance, which titanium certainly is, is an ideal conservation attribute. Furthermore, the availability of various alternate materials with overlapping properties and capabilities, each abundant enough to satisfy all users, increases our flexibility.

In another respect, titanium resembles magnesium. Levels of production of magnesium were very modest up to the beginning of World War II; between 1939 and 1943, 15 magnesium plants were constructed—largely with government money—until production reached a peak of 183,584 tons and an annual capacity of nearly 300,000 tons. Consumption, however, never exceeded 132,698 tons—its wartime peak. After the war ended and government support for magnesium was withdrawn, the industry continued on a much lower level. Wrought products and powder became of proportionately less importance while castings became the mainstay of the industry. (See Table). Thought should be given to the motives that led to the lively action in magnesium casting, in order to ascertain whether the same reasoning is applicable to titanium today.

Obstacles to Growth

In time, wrought magnesium products may again assume a position of dominance. The thorium-zinc alloy has enhanced the metal's properties in sheet form at moderately elevated temperatures and the HAE coating, developed by Frankford Arsenal, has improved its durability in corrosive environments. Nevertheless, die-cast magnesium also shows high promise of growth, and in general it may be said that the magnesium industry has a promising and healthy future prospect. Castings as the mainstay have kept the industry alive over a rocky transition period. There is no reason to suppose that improvement and enlargement in the wrought sector will be at the expense of castings in the future. If castings can play a similar role in titanium, the foundry industry will benefit—and so will the wrought titanium industry and nation at large. We believe it is worth a try.

There are several obstacles to the growth of a titanium foundry industry. Two factors stand out as warranting extended discussion: selection of non-reacting mold materials and cost of the metal itself. Other obstacles exist, but can be covered more briefly. For example, the need for an inert atmosphere will probably always be inherent in titanium casting. However, vacuum metallurgy and inert atmos-

phere metallurgy are becoming more and more widespread with each passing year. It is still a technique reserved for specialty alloys, but an ever-growing list of applications have been found to justify specialty alloys on an economic basis.

Familiarity with the techniques and availability of the equipment for this type of melting are leading to progressive reductions in cost. In essence, the inert atmosphere requirement is a burden to be carried and one that necessitates economic evaluation to determine whether the added cost is justified in terms of superior performance of the product. But where cost is justified, inert atmosphere handling is not necessarily an obstacle.

Similarly, machining of titanium is a specialized technique; but once learned it imposes no unusual burdens of cost or special equipment.

A more serious obstacle is the ready reactivity of the metal with most conventional mold materials, especially in view of the high melting temperature of titanium. This temperature can be expected to drop somewhat as improved casting alloys are developed. The pure metal melts at 3035 F., but the alloy 6 Al-4 V melts in a range between 2786 and 2976 F. Other alloys with lower melting points can be expected to make their appearance as casting of titanium becomes more general.

Mold Materials

For mold materials, the most reliable is machined graphite. This material holds a close tolerance, may be re-used a number of times and imparts only slight surface contamination. Unfortunately, it is an expensive material to use and is limited in size of casting. It should be regarded as a starting point. In applications in which titanium enjoys clear and marked superiority over competing metals, castings in machined molds are already proving their worth.

But isolated or individual company successes have been reported with a number of other mold materials, including rammed carbon molds, shell molds of carbon bonded with phenol formaldehyde, zircon shell molds washed with graphite, and zircon impregnated or bonded with titanium powder to make an oxygen-deficient ceramic. Enough work has been done to establish that wide ranges of quality are possible and that quality of titanium castings is related to cost. A low-cost, rough-surfaced titanium casting is feasible of production at a very much lower cost than the high quality, machined graphite mold product.

The cost of the titanium metal used in casting is also subject to considerable variation. First, there is the variation in quality of scrap. Most work to date has been done with good quality sponge as melting stock. Inherent in the present situation is the possibility of exploiting the availability of low-grade sponge and low-grade scrap for the production of castings having reasonably adequate strength (relative to, say, cast iron) with very superior corrosion resistance. Many of the applications suggested for titanium castings in the chemical industry, to cite only one obvious and outstanding example, are not very highly stressed. Achievement of a reasonably sound casting in titanium, using low-grade scrap and rammed carbon mold, should bring the product down almost within reach of stainless steel. In view of the very long life of titanium in corrosion service, the favorable economic position of such low-cost castings is obvious.

In one further respect, an economy may be achieved. Considerable metal is tied up by present casting practice in the form of gates, sprues, and risers. With an expensive metal like titanium, considerable research would be justified into unconventional ways of getting the metal into the mold. Added costs of mold design and pouring arrangements might more than be justified by reduced requirements for melting stock. Comparatively little evidence of investigation in this direction has appeared in the literature.

U. S. MAGNESIUM SHIPMENTS 1955-1957*
(short tons)

	Castings: Sand	Castings: Perm. Mold	Castings: Die	Total	Wrought Forms	Primary Ingot Production
1955	7911	3074	2958	13,944	10,586	61,130
1956	8301	1159	2451	18,083	12,692	68,347
1957	7494	885	2047	15,166	10,959	78,865

*Figures from Table supplied by The Magnesium Association

Department of Defense

In the event that an attractive military application, such as would require titanium casting, is presented to a military department, additional research related to the end item in question might well be justified; moreover, if a number of such items should be proposed, military research in titanium casting methods could be undertaken at a much more substantial level than at present.

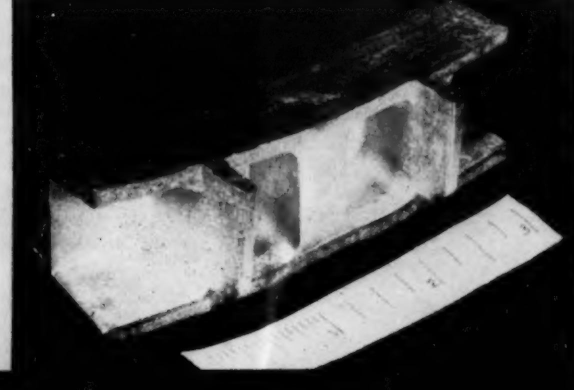
One final note. The question may be asked as to whether the Department of Defense has established any policy with respect to titanium casting, or the preferential employment of titanium in military equipment. This is a complicated question, but one that can be answered. First of all, the Department of Defense has a definite policy that research in any material should proceed without any restriction based on considerations of relative availability of current supply.

The fact that titanium is a small-volume material does not inhibit research into potentially massive military uses for it. Secondly, our policy requires that, within the limits of practicality, the material that contributes essential performance characteristics to an end item shall be used for that item. Third, we follow the practice that the entire cost of the item, including both initial purchase price and maintenance for the life of the item, is to be considered in developing its specifications and design. We do not have any special policy that requires a preference to be given to any material over another within limits of availability.

We believe that military designs and engineering and scientific developments should not be complicated with considerations of economic health of any particular industry. But where a material can do the best job, that is where we want to use it. We believe that, measured by that standard, titanium castings have much to offer.

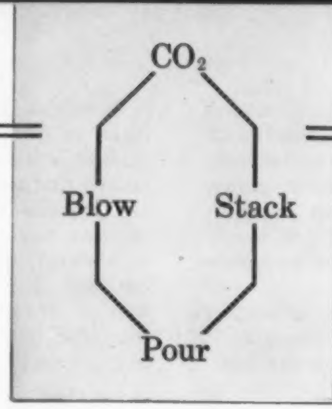
Titanium Castings for Aircraft

Pad longeron is titanium casting.



Inner ring stiffener is another use.

MARQUARDT AIRCRAFT CO. PHOTOS

MOLDING PROFIT CYCLE =  = $

J. N. Carter
Works Manager
American Foundry & Machine Co.
Salt Lake City, Utah

Mold shooting, CO2 gassing, stack molding are combined at American Foundry & Machine for high speed production of steel castings

Dumping mixed sand into hoppers on mezzanine floor level above the core shooters. CO_2 gas is piped from bank of cylinders on right to gas-roll-over-draw machine below.

Mold shooting – CO_2 gassing – stack molding . . . these three techniques have been combined at American Foundry & Machine Co. for high speed production of molds for steel castings. Much of the equipment needed for this process was built right in the plant by our own personnel.

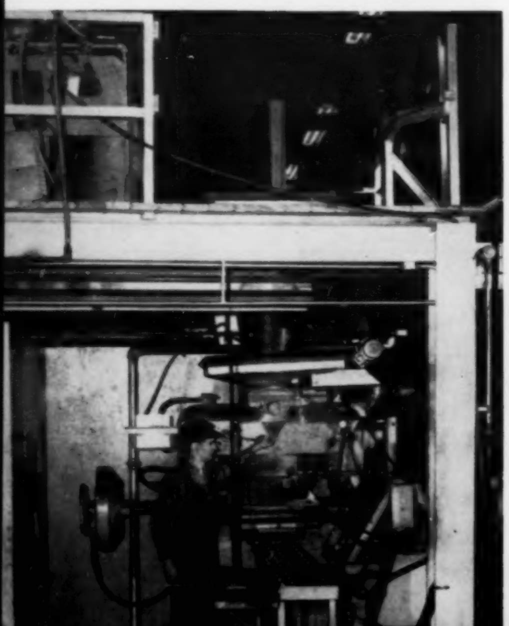
A complete, ready-to-pour, mold section is made every minute with this new installation. Mold is shot in 30 seconds with a core shooter; it is then transferred to a gassing machine which rolls over the mold simultaneously with CO_2 treatment. Cope and drag patterns are drawn away and mold is ready for stacking. Each mold section is really the equivalent of a complete mold since the lower face forms the cope and the upper face forms the drag.

Sand preparation for the system is fully mechanized and automated. Sand is drawn from silos, weighed in an activator set on load cells, pneumatically transported to mixers, and blended with sodium silicate binder.

The following picture sequence illustrates the essential steps in the shoot-gas-stack system at American Foundry and Machine:

First step in making mold is to spray the pattern and box with silicone parting agent to prevent sand from sticking. Note the drag-out conveyor designed to move mold from core shooter to gassing-roll-over-draw machine on right. It takes only seconds to prepare the pattern and shoot-mold.

CO_2-hardened mold removed after draw.



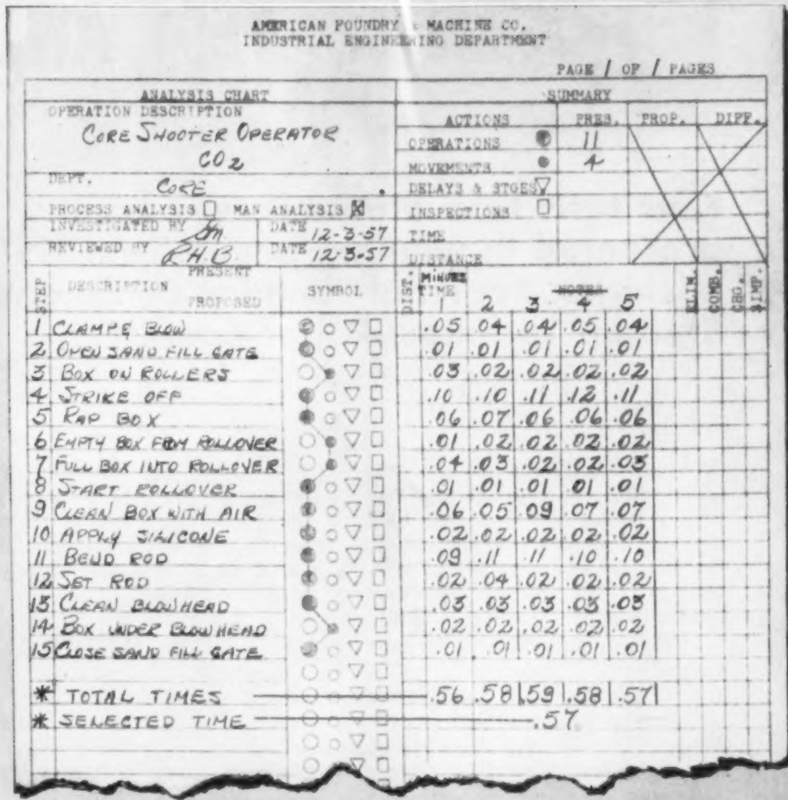
Core shooter is located directly below hopper. Operator is actuating shooter and it will fill mold box. Also shows complete unit-shooter, drag-out conveyor and gassing-roll-over-draw.

Box is inserted in gassing-roll-over-draw machine. This machine clamps mold in position, gasses at 100 psi for 14 seconds, rolls over mold and draws it from the pattern. Total elapsed time for this sequence of operations is just 30 seconds.

Variety of patterns used in CO_2 stack molding.

Ten molds stacked on special clamps for delivery to the pouring floor. Number of molds stacked varies with different jobs. Weight of individual mold sections used at American Foundry & Machine Co. vary from 20 to 55 lb. Rig facilitates quick, positive clamping and easy handling by crane. Note paper plates used on the pouring cups to keep dirt out of finished mold assemblies.

Pouring stacks with steel from bottom pour ladle.



AMERICAN FOUNDRY & MACHINE CO.
INDUSTRIAL ENGINEERING DEPARTMENT

PAGE 1 OF 1 PAGES

ANALYSIS CHART

OPERATION DESCRIPTION: CORE SHOOTER OPERATOR CO_2

DEPT. CORE

PROCESS ANALYSIS ☐ MAN ANALYSIS ☒

INVESTIGATED BY Jm DATE 12-3-57

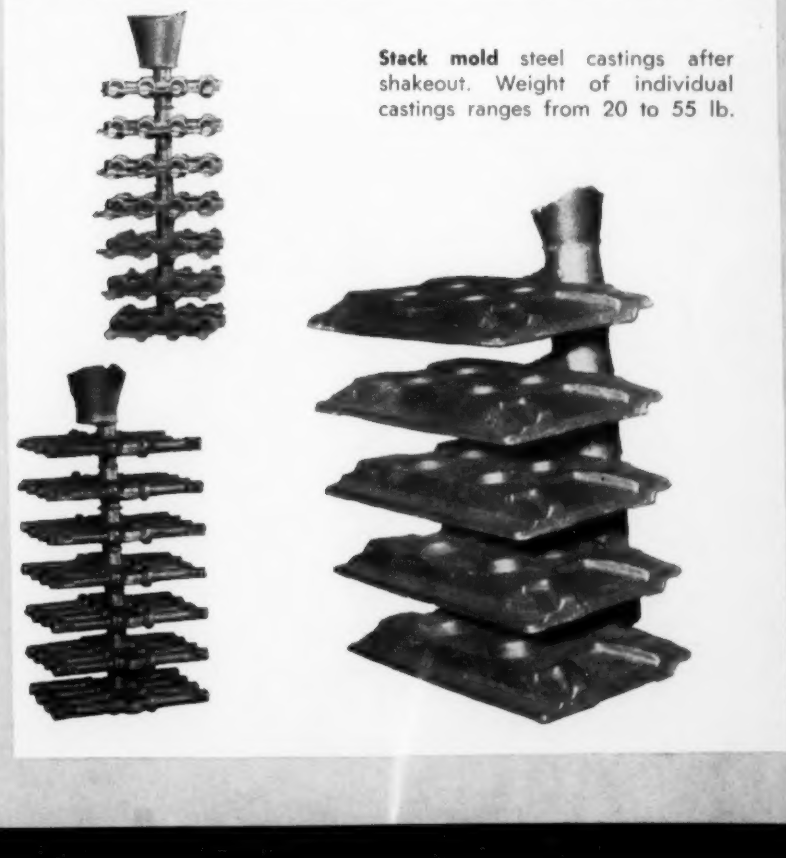
REVIEWED BY RHB DATE 12-3-57

SUMMARY

ACTIONS	PRES.	PROP.	DIFF.
OPERATIONS	11		
MOVEMENTS	4		
DELAYS & STGES			
INSPECTIONS			
TIME			
DISTANCE			

STEP	DESCRIPTION PRESENT / PROPOSED	DIST.	MINUTES TIME 1	2	3	4	5
1	CLAMPE BLOW		.05	.04	.04	.05	.04
2	OPEN SAND FILL GATE		.01	.01	.01	.01	.01
3	BOX ON ROLLERS		.03	.02	.02	.02	.02
4	STRIKE OFF		.10	.10	.11	.12	.11
5	RAP BOX		.06	.07	.06	.06	.06
6	EMPTY BOX FROM ROLLOVER		.01	.02	.02	.02	.02
7	FULL BOX INTO ROLLOVER		.04	.03	.02	.02	.03
8	START ROLLOVER		.01	.01	.01	.01	.01
9	CLEAN BOX WITH AIR		.06	.05	.09	.07	.07
10	APPLY SILICONE		.02	.02	.02	.02	.02
11	BEND ROD		.09	.11	.11	.10	.10
12	SET ROD		.02	.04	.02	.02	.02
13	CLEAN BLOWHEAD		.03	.03	.03	.03	.03
14	BOX UNDER BLOWHEAD		.02	.02	.02	.02	.02
15	CLOSE SAND FILL GATE		.01	.01	.01	.01	.01
*	TOTAL TIMES		.56	.58	.59	.58	.57
*	SELECTED TIME				.57		

Time study shows how the operations pictured here are all accomplished in less than one minute.



Stack mold steel castings after shakeout. Weight of individual castings ranges from 20 to 55 lb.

HOW TO TEST AND EVALUATE CORE OIL

Rodney L. Boyes/
General Motors Institute
Flint, Mich.

Four tests to evaluate core oil are presented in winning paper from 1957 Michigan Regional Foundry Conference Student Technical Paper Contest

Are you often in a quandry over selecting the core oil that will give you the fastest baking time and the desired tensile strength at the least cost per ton of core sand mix? If so you may find these four relatively simple tests a good guide in evaluating and choosing the best core oil for your foundry.

The importance of a good core oil for foundry use is well known. The oil has the main function of providing baked tensile strength necessary for a core to withstand the force of the molten iron being poured into a mold and to withstand a certain amount of rough handling which is unavoidable in the transporting and storage of cores.

Method of Mixing

In order to test a core oil, the core mix must be carefully prepared. The ingredients must be accurately and properly mixed. Before mixing any test mix a dummy batch of core sand should be run in the muller to remove any foreign substances left from mixing other materials and to coat the muller surfaces with oil.

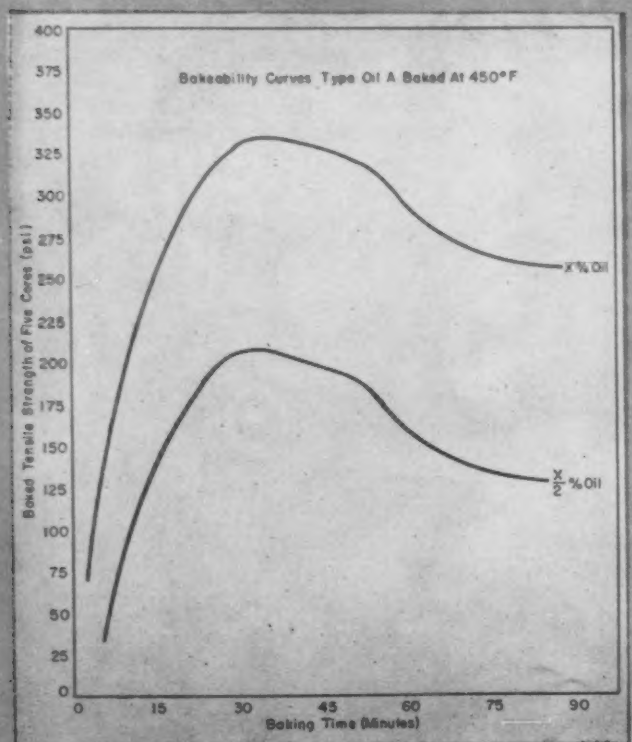
An AFS 50-70 testing sand provided the base for the test mix. Each batch used 4500 grams of the sand. Sixty grams of flour and 120 cc of water are added to each core sand mix. For accurate measuring of oil the beaker to be used should be filled with core oil, then tipped over and allowed to drain at a 45 degree angle for 60 seconds. After this is done the beaker (containing a film of oil) is weighed. Having determined the tare weight, the next step is to carefully weigh out the desired amount of oil needed for a particular batch of sand.

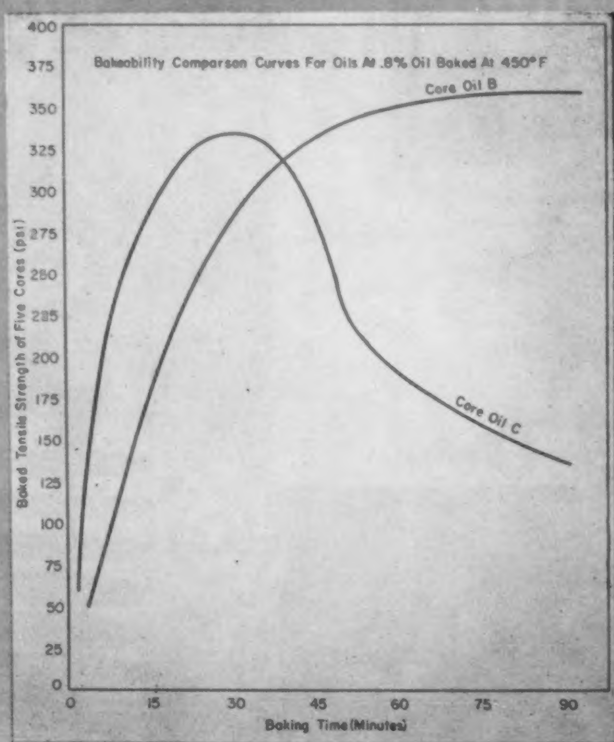
The sand and flour are placed in the muller and mixed dry for 60 seconds. The water is then added and mixed for 60 seconds. Core oil is added, taking care to drain the beaker at a 45 degree angle for 60 seconds. The mix is mulled for six minutes. After completing the mixing cycle, core sand is placed in a closed container and is stored pending the next operation.

The method of making cores and testing them for baked-tensile strength has been established by AFS. Core sand is rammed into a figure 8 box with equipment designed for this purpose. Core is removed, baked and then broken on a special testing machine. Tensile strength can be directly read on the machine.

Of any one core sand mix, 25 test cores are made. The cores are split up into five groups of five each and baked for periods of 30, 45, 60, 75 and 90 min at 450 F. After baking, each group of cores is checked for tensile strength. The tensile strengths of each group of cores are totaled. This gives the total combined strength of five cores. If any one reading in a group of five is inconsistent when compared with the other four, this figure should not be used in the test results.

A data sheet may be designed to handle the above information. The core sand can also be tested for moisture content, temperature,





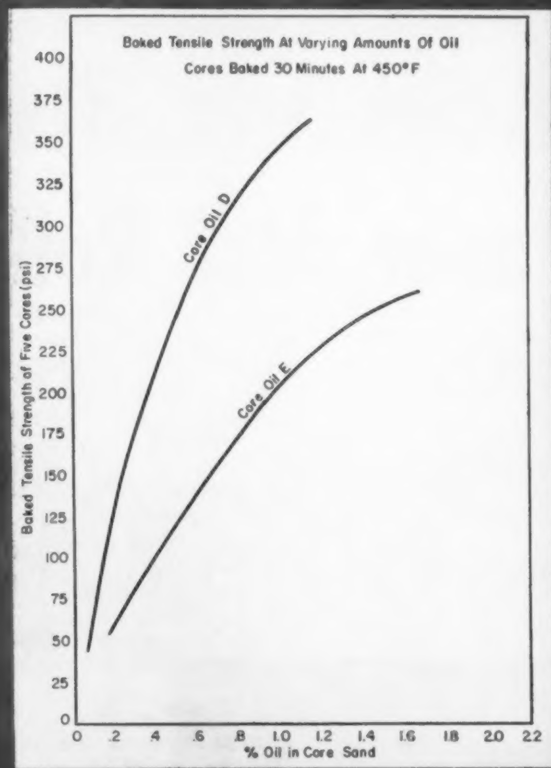
and green compression strength. This information may also be placed on the data sheet.

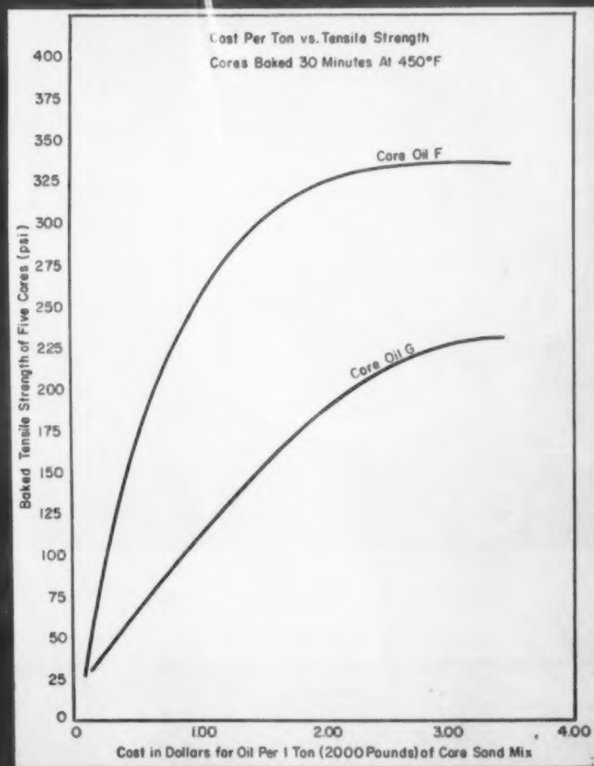
Bakeability Curves

After collecting the test data, a comparison must be made of the bakeability characteristics. Usually in testing any one core oil, five core mixes are made.

The bakeability curves show baked tensile strength versus baking time. The object is to show trends on how baking time affects strength. The bakeability curves in Fig. 1 show this relationship for one mix with X per cent oil and another with 1/2-X per cent. By constructing the curves a definite pattern can be seen between the various compositions of the same oil. Note that in 30 min core oil "A" reaches its maximum strength. However, after 45 min the oil tends to overbake and loses its strength rapidly.

A curve which constantly increases, as far as baked tensile strength is concerned, would be the most favorable oil to use. An oil which reaches its maximum strength quickly would also be desirable. Generally all bakeability curves of mixes containing the same oil will follow the same general pattern regardless of per cent oil contained.





Bakeability Comparison Curves

In order to evaluate core oils on the basis of their bakeability characteristics, curves of several different oils (the oils to be compared) should be presented on one graph. This is done by taking the bakeability curve of each oil at 0.8 per cent oil and possibly 1.2 per cent, or any other per cent desired. Normally only one curve of this type needs to be drawn.

Figure 2 is a sample graph showing core oil "B" and core oil "C". Core oil "B" is a slow baking oil. That is, it reaches its maximum strength after a long period of baking time. Core oil "C" reaches its maximum strength quickly. However, the strength of core oil "C" drops off rapidly if the cores are overbaked even a slight degree. Each oil has a definite advantage: core oil "B" does not overbake; core oil "C" reaches its maximum strength rapidly. It would depend upon the actual case as far as determining which core oil would be the best suited for a particular use. Many core oils can be eliminated from consideration for a specific job by this type of comparison.

Comparison of Baked Tensile Strength

By comparing the baked tensile strength with the amount of oil needed to reach that strength, a relationship between the oils can be set up. A curve is developed for a given oil by using the strength of five cores from each core oil mix (of the particular oil) after baking for 30 min.

Figure 3 is a graph comparing core oil "D" and "E." On this graph it can be seen that core oil "D" produces a much greater strength at a lower per cent oil content. To produce the same strength, much more of "E" is required than "D." This comparison proves which oil is "the strongest."

However, this should not be the deciding factor in determining which oil should be used. Even though more core oil "E" is required to reach a given strength, it still may be *cheaper* to do so with "E" than "D." Therefore this curve is used mainly for quality comparison only.

Comparison of Cost and Strength

The cost of a satisfactory core oil will probably determine whether it will be used on a production basis or not. A comparison between oil costs is plotted similarly to the method used for showing baked tensile strength vs per cent oil compositions. The only difference is that the abcissa is expressed in dollars per ton of core sand mix rather than per cent oil content.

In the graph comparing costs of core oil "F" and "G" it can be easily determined what the cost would be to buy the oil necessary to produce a ton of core sand at a desired strength. Core oil "F" is superior to core oil "G" on this basis of comparison. It would cost $2.33 for enough of oil "G" to make a ton of core sand with a baked tensile strength of 200 psi, whereas $0.67 spent on oil "F" would buy sufficient to produce a ton of core sand of equal strength.

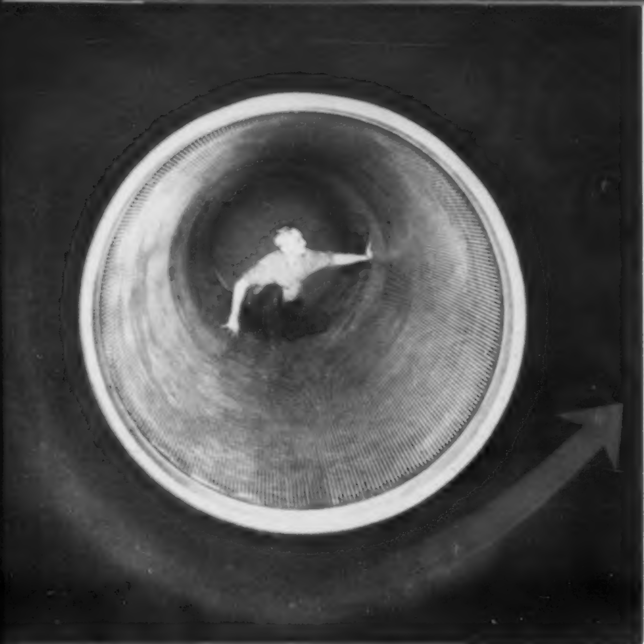
It must be remembered that this curve does not show the bakeability characteristics of the oils. It has the specific purpose of showing the cost to produce a given core sand which is baked for one given length of time.

Conclusion

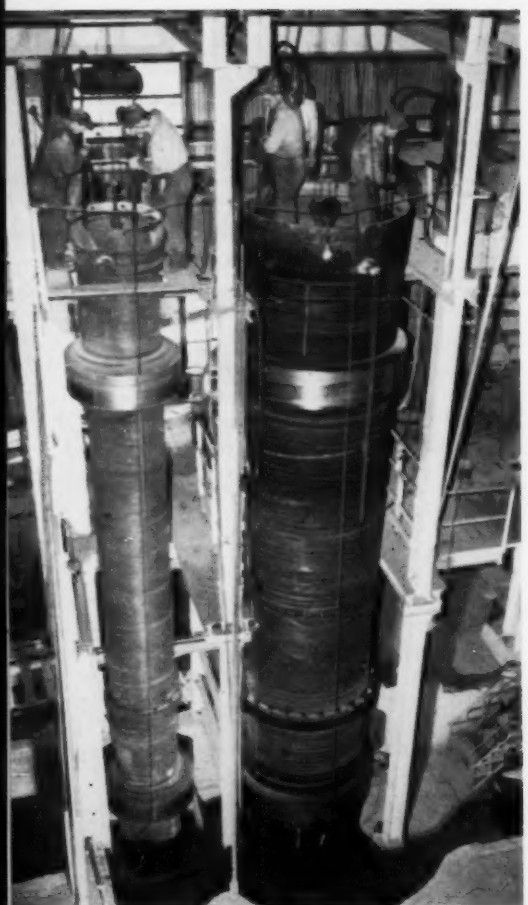
By comparing core oils with the aid of these curves, an oil may be selected to suit any particular foundry's needs. For example, if the possibility of overbaking is prominent, a more stable oil should be used.

The cost curve will probably be the determining factor in most foundries. It should be stressed, however, that this should not be the final deciding factor.

The bakeability characteristics must be considered. The particular need will determine which oil is most acceptable.



60,000 lb. Stainless Steel Paper Mill Roll



Ramming operation of two large molds. Men are lowered into mold at right to apply sand to walls.

Core oven, 37 ft high, passes hot air at 350 F through as many as nine molds for overnight baking.

SANDUSKY ROLLS FOR PAPER MAKING

■ Paper is consumed in greatest quantity where industry, commerce and education are most highly developed. The United States, with only seven per cent of the world's population, consumes approximately 55 per cent of the world's total paper production.

In 1945 an average of 282 lb of paper products were consumed per person in this country. By 1955 this figure had jumped to 418 lb and is still climbing at a steady rate.

The paper manufacturing process starts with a mass of wet, pulpy cellulose material, which is gradually pressed flat and dried as it passes through the paper-making machine. Perforated suction press rolls, the type produced by the Sandusky Foundry & Machine Co., remove large quantities of water from the pulp in the paper-making process by a combination of squeezing and vacuum suction.

These perforated suction rolls were the invention of H. W. Millspaugh, who was one of the founders of the Sandusky Foundry and developed many of the techniques for manufacturing these rolls.

In order to speed up existing paper machines and build new ones of sizes and speeds required to satisfy the world's needs for paper, larger, more efficient and stronger rolls than could be made of bronze had to be provided. Stainless steel proved to have the necessary qualities, namely castability, machineability, strength, corrosion and abrasive resistance exceeding bronze.

SANDUSKY FOUNDRY & MACHINE CO.

JACK H. SCHAUM / *Editor*

Stimulated by the fabulous growth in the use of paper by the American public, Sandusky Foundry & Machine Co. has now completed a five million dollar expansion program. This Ohio foundry specializes in centrifugal casting of special-purpose rolls required in large numbers for the high-speed conversion of paper pulp into finished paper products.

The expansion was the direct result of technological change. Larger paper mills, operating at higher speeds and utilizing more corrosive media, began to require more and more rolls made of stainless steel rather than the conventional bronze alloys heretofore found adequate.

Acting under the pressure of these new demands on the part of paper mill manufacturers, the decision was made to investigate the extensive equipment changes required to add stainless steel to its bronze melting and casting program.

Careful study by top management revealed certain other requirements that had to be met by any new equipment installed. Being an integral component of the rapidly growing paper industry, new facilities had to be capable of: 1) supplying greater daily tonnages of molten metal, 2) melting rapidly, 3) furnishing quality control, and 4) melting both steel and non-ferrous alloys without any danger of contamination of one alloy with another.

The problem was further complicated by the plant being located only two blocks from the center of town and production facilities were literally bursting at the property seams. Consequently the new equipment had to produce more molten metal per square foot of plant area.

After carefully analyzing their problems, management decided that the ultimate solution was to replace slow, bulky melting units with streamlined, fast, induction-melting furnaces capable of melting both copper-base alloys and stainless steels. Probably the world's largest installation of induction furnaces in a foundry is now represented in the battery of four 10,000-lb, one 5000-lb, one 2000-lb and one 500-lb capacity furnaces. As many as five of the six furnaces can be operated simultaneously, so that over 42,000 lb of induction melted steel or bronze can be made available at one time for casting.

Other melting equipment in the plant includes a 20,000-lb direct-arc furnace which adds capacity sufficient to cast steel rolls weighing over 60,000 lb. Also available in the melting department are three horizontal rotating gas-fired furnaces capable of melting 13,000 lb of bronze apiece, thereby making it possible to cast bronze rolls weighing over 75,000 lb.

Induction Melting Equipment

Frank Hamilton, manager of production control, was enthusiastic when he praised the induction-melting equipment at Sandusky Foundry. "Induction melting represents just about the ultimate in flexibility. It permits us to regularly melt from 40 lb to over 40,000 lb in both ferrous and non-ferrous alloys."

The equipment, as shown in the layout diagram, consists of two 1250-KW, 960-cycle, 800-volt generators driven by 4160-volt synchronous motors. The generators may be operated singly or in parallel, feeding power to one or more of the six furnace stations.

Power can be distributed as follows:

1) With generator A operating independently:
   a) station 1 may be operated at a maximum of 300 KW, or
   b) station 2 may be operated at a maximum of 950 KW, or
   c) station 1 and 2 may be operated simultaneously at 300 and 950 KW respectively, or
   d) station 3 may be operated at a maximum of 1250 KW, or
   e) station 4 may be operated at a maximum of 1250 KW, or
   f) stations 3 and 4 may be operated at a maximum of 1250 KW, or
   g) stations 1, 2, and 4 may be operated simultaneously; however, the maximum total power must not exceed 1250 KW.
2) With generator B operating independently:
   a) station 5 may be operated at a maximum of 1250 K or
   b) station 6 may be operated at a maximum of 1250 KW, or
   c) stations 5 and 6 may be operated simultaneously; however, the maximum power drawn from the generator must not exceed 1250 KW.
3) With generators A and B operating in parallel:
   a) stations 1 and 2 may be operated simultaneously; or independently, or
   b) stations 3, 4, 5 and 6 may be operated simultaneously or independently; each of these stations may be operated at a maximum of 1600 KW; however, maximum total power drawn must not exceed 2500 KW, or
   c) stations 1, 2, 4, 5 and 6 may be operated simultaneously or independently; however, maximum total power drawn must never exceed 2500 KW.

This arrangement gives extreme melting flexibility. When large heats up to 42,000 lb are desired, Stations 3, 4, 5 and 6 are run simultaneously. For very small melts, down to 40 lb, a clay graphite crucible is placed in the 500 or 1000-lb furnace for melting.

Induction melting is fast melting—a 10,000-lb bronze heat can be melted in 1-1/2 hr, while a similar weight of steel is ready for pouring in 2-1/2 hr. For extra fast melting as much as 1600 KW's can be directed into any one of the large furnaces. Quality control is simplified by the fact that melt-down losses are small and consistent from heat to heat!

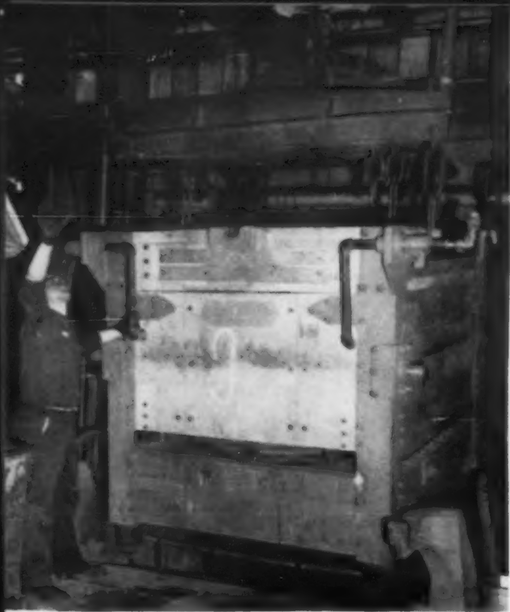
As a consequence about 60 per cent of all furnace charges are comprised of machine-shop turnings and chips.

Use of Chips and Turnings

Since all the rolls cast in the foundry are subsequently machined in an adjacent shop, large quantities of metal turnings are generated.

The ability of induction furnaces to melt down this normally difficult material quickly with a minimum of loss is another plus factor which favored selection of this type of melting equipment.

Because of the large variety of alloys handled in the foundry, care must be exercized to prevent contamination of successive heats. It

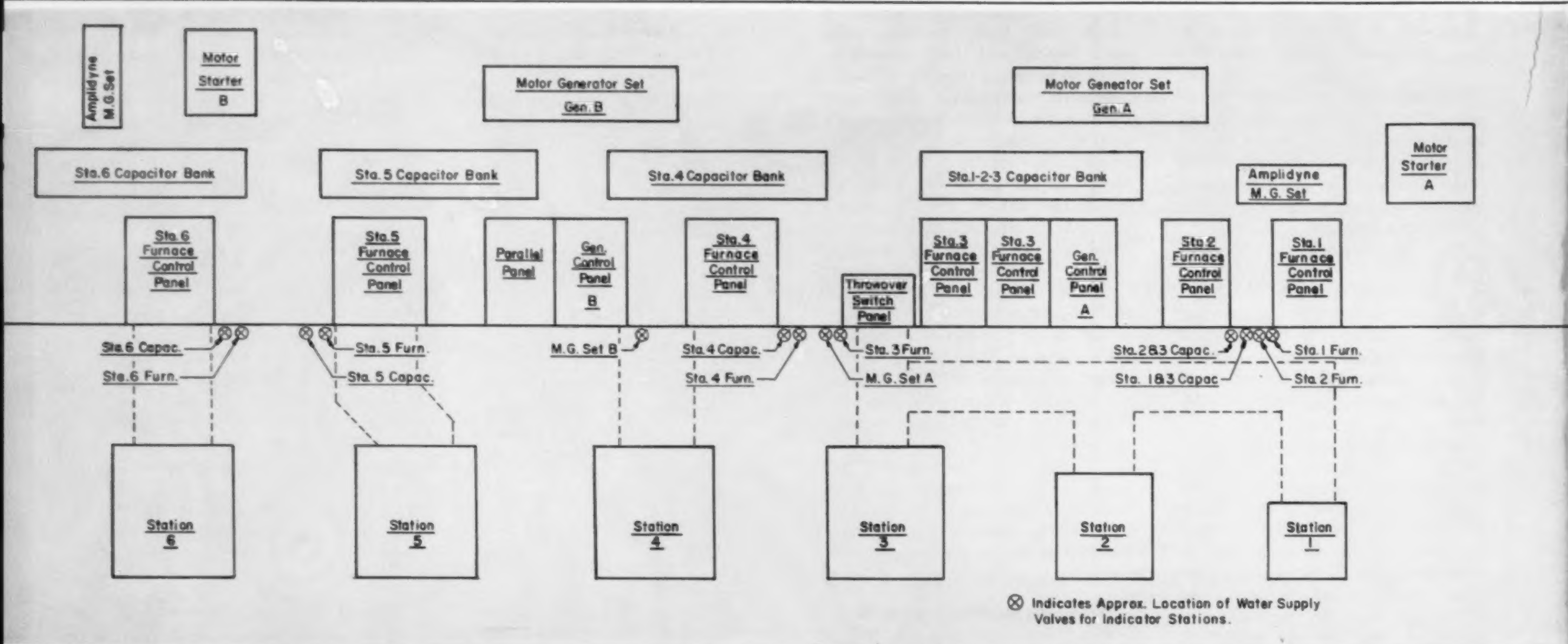


Switching furnaces takes 5-10 min, eliminating time-consuming relining.

would be impossibly time-consuming to reline furnaces to suit particular alloys and too expensive to reserve a specific furnace station for each individual alloy family. Fortunately the induction-melting installation solved this problem.

Since the heating coil and lined furnace crucible are an integral part of the furnace box it is relatively simple to remove one furnace box reserved for a particular alloy and replace it with another. Electrical contact is made from the furnace box to the power system through

Rotating attachment dumps metal chips and turnings into furnace.



Floor lowered to allow ladle to receive melt from 10,000-lb furnace.

pressure contacts which complete the electrical coupling when the crane man sets the box into the furnace pit.

Quick-Switch Furnaces

The only other connections to the furnace are a cooling water inlet and outlet made with a quick-disconnect coupling on each furnace trunnion. According to Foster Baker, foundry superintendent, a 40-year man with Sandusky, "It is only a matter of 5 to 10 minutes elapsed time for the overhead crane to lift a furnace box out of the pit; move it down the foundry bay to the storage area; pick up another furnace box and set it back into the same pit."

The following supply of furnace boxes meets all the requirements of sizes and avoids undesirable contamination between different alloy systems: nine 10,000-lb furnace, two each of the 5000-lb, 2000-

lb, 1000-lb and 500 lb furnaces. All furnaces use rammed linings. A life of anywhere from 20 to 100 heats is obtained, depending upon the particular alloy involved.

With over 20 non-ferrous alloys, 27 high-alloy steels, 24 plain carbon and low-alloy steels, a system of control has been developed so that all scrap is meticulously segregated, accurately identified and carefully stored for future remelt in the foundry. The key storage unit in this program is a common 50-gal steel drum. Chips are automatically conveyed from lathes or shoveled by hand into the drums.

ADVANTAGES OF INDUCTION MELTING

■ Induction melting is ideal for the work done at Sandusky for several reasons.

1) The alloys are fairly expensive and the economies obtained because of the low alloy losses during melting make induction melting advisable.
2) With no other type of melting would such flexibility, both in heat size and alloy variety be possible.
3) A large percentage of each charge is chips and borings. With electric-arc or gas melting, high alloy losses are incurred. Recoveries with induction melting are very high.
4) Induction furnaces are simple to operate and do not require highly trained melters familiar with slag practices, oxygen blowing, etc.
5) Precise temperature control is easily obtained.
6) Stirring action in the induction furnace assures uniformity of temperature and composition in all parts of the melt.

Charging

Fork-lift trucks, specially equipped with barrel-gripping devices, transport these barrels of chips and turnings from the machine shop to a storage area adjacent to the foundry. Low-carbon stainless steel turnings are treated to remove the oil before they are placed in storage for subsequent melting. Barrels of similar alloys are stored in designated areas, where they are stacked vertically as much as six barrels high.

Lift-truck operators bring the barrels from storage to the induction-furnace area and temporarily place them alongside of the furnace scheduled for melting. These barrels can be seen in several of the photos used in illustrating this article. Complete charging of 10,000 lb can be accomplished in a matter of ten minutes or less. Barrels are quickly raised by fork lift and rotated 180 degrees, dumping contents into furnace.

Although holes are provided in the bottom of barrels to allow for drainage of cutting fluids, the chips are still apt to contain considerable moisture when charged into the furnace. As soon as the power is turned on to the charge, the heating action of the induction current converts this moisture into steam.

Melting

An air blast is utilized to encourage movement of this moisture up through the charge and into the ventilating system. This jet of compressed air is directed vertically over the center of the charge during the first stages of melting. The jet soon draws out of the charge all the steam generated.

When the melt reaches the proper tapping temperature, the floor immediately in front of the furnace is lowered on a hydraulic ram, creating a pouring pit. A preheated ladle is positioned in front of the furnace, which is emptied by tilting. When the ladle is removed the floor returns to its flush floor position. This innovation eliminates safety hazards and at the same time providing working area for recharging furnace. Depending on the size of roll to be cast, additional furnaces can be tapped into this same ladle until it contains the amount of metal required to do the casting.

Molding

Since all castings are centrifugally produced, molding operations are distinctive to this process. Flasks are hollow steel pipes perforated with holes for venting. Two or three collars are located around the outside of these flasks to permit the flask to be spun horizontally on the centrifugal casting machine. To line the flasks with sand they are set vertically in a special ramming tower. Four ramming towers are available for this operation.

Molders ram a layer of molding sand to a thickness of 1 to 3 in. around the inner periphery of the flask. Inside diameter of the sand shell is formed by a brass plug of the proper diameter and measuring 30-in. long. This plug is suspended from a steel cable. The cable is attached to a four-armed spider, anchored on top face of plug. Spider also keeps plug centered in the flask. The plug is lowered into the vertically-positioned flask and sand rammed into the annular space between flask and plug.

With flasks large enough to permit, a molder stands on top of the plug and rams sand with a pneumatic or hand sand rammer. If the flask has too small a diameter to permit a man to get into it, ramming is done with long-handled ramming tools. As the sand is rammed, the plug is raised in steps of 6 in. until the complete length has been rammed. Since the plug has no draft on it, the result is a perfectly cylindrical mold cavity centered in the flask.

Thirty-three years' experience with Sandusky Foundry backed up the emphatic comment by Ed Hirt, molding foreman, that "centering is doggone important in centrifugal casting if you expect to hold down your scrap." The least amount of unbalance will introduce undesirable vibrations when the mold is spinning at high speeds and cause an eccentric casting which must be scrapped. One flask can be used for a variety of diameters by utilizing different sized plugs, and various lengths by shortening the effective length of the flask by bolting into it a stop-off plate. After the mold has been rammed it is placed in a core oven 37-ft high, to take care of the longest of these rolls.

Molds set on a grate and hot air at 350 F passes through overnight. The core oven is sufficiently large to handle eight or nine molds at a time.

Pouring melt into spinning mold must be carefully timed to avoid laps in metal.

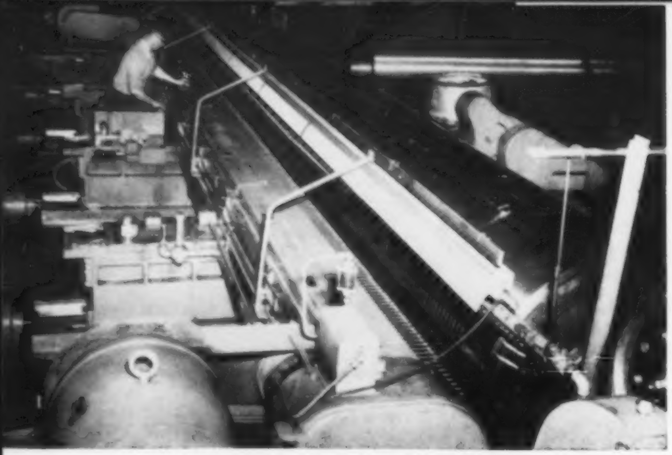
Centrifugal Casting

Mold surface is usually coated with a refractory wash before entering the drying oven. Dried molds are removed from the oven and taken by crane to the centrifugal casting department. Equipment here includes four large and three small horizontal casting machines plus one vertical.

Casting machines are located between thick concrete walls. When they are in operation the top is covered with a movable steel roof. Sliding doors close each end, thereby providing complete protection to all men working in the area.

The weight of the largest of these roll flasks, measuring 58 in.-diameter x 35 ft-long, is 35 tons. This mold produces a cast-hollow roll weighing more than 75,000 lb. Molds are spun at speeds ranging from 350 to 1450 rpm, depending on their size. The speed of four 75 and 150 hp DC motors that drive each casting machine is controlled by a man in a control booth next to the machine. He adjusts

Casting machine located between concrete walls, steel roof and sliding doors.



Papermaking machine roll perforated with thousands of holes, 266 drilled at once.

the speed to create a centrifugal force approximately 70 to 75 times that of gravity at the median wall of the casting.

The weight of metal poured into the spinning mold determines the inside diameter of the casting. Metal is poured from the ladle into a pouring box which has a horizontal, tubular gate protruding several feet into the spinning mold. The pouring time is a critical factor and is carefully measured by stop watch in the hands of Russell Baker, foreman of melting and casting. Improper pouring speeds can lead to laps in the metal, necessitating scrapping of the casting.

As soon as the metal has started to enter the mold a water spray is directed at the outside of the flask over its entire length to minimize cooling stresses. Mold rotation during pouring is maintained constant. After pouring bronze, one of the men skillfully directs a stream of water on the inside surface in such a manner as to produce rapid and uniform cooling throughout the length of the hollow roll. Spinning is stopped at the end of about 45 min. and the mold containing the casting is moved to the cleaning department.

Shakeout

Men on the second shift shake out the castings by locking the mold in a vise contacting several large, vibrating hammers. A combination of vibration and a strong pulling action slides the casting out of the mold.

After shakeout, swing frame grinders and wire brushes are used to clean off surface sand. Alloys requiring heat treatment can be normalized, tempered, or annealed in a 35-ft long car-bottom electric furnace (1000 KW).

Quality control is an essential which is maintained by the laboratory of the metallurgical department. A process sheet is prepared for each new casting order and accompanies the order in every operation from charging of raw material to transfer of parts to shipping department.

Machining

When the hollow-cast roll leaves the foundry it has barely begun its journey toward a finished product. The rolls must now be accurately machined and drilled in the machine shop. Huge 72-in. engine lathes capable of handling rolls 37-ft long now turn the outside and bore the inside to the finished accurate dimensions required.

As many as half a million holes are next drilled through the rolls on automatic spindle-drilling machines capable of drilling as many as 266 holes simultaneously in a straight line and then indexing for the next row. One such machine alone represents an investment of a quarter of a million dollars. The whole drilling operation alone may require anywhere from two to three weeks' time.

In conversation with W. S. Pyson, public relations director of Sandusky Foundry & Machine, he pointed out that, "Although papermaking rolls represent the bulk of the production here at Sandusky, many other industries are being served by these high-quality centrifugal castings." And to back it up he provided a partial list of cylindrical components supplied recently for industrial furnace, marine, petro-chemical, ordnance, atomic power and general industrial applications.

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SOLIDIFICATION AND RISERING OF GRAY IRON CASTINGS

By

Clyde M. Adams, Jr.*, Merton C. Flemings* and Howard F. Taylor**

ABSTRACT

This work represents the detailed conclusions of an eight-year research program on solidification and risering of gray iron castings. Experimental data and theoretical analyses are used to delineate the fundamental variables for determining shrinkage in gray iron.

The natural reduction in volume accompanying the cooling of gray iron from the liquid to the solid depends on metal chemistry. However, the size and location of voids resulting are dependent not only on chemistry but also on factors which influence the movement of the casting surface. These are: 1) size and shape of the casting, 2) action of atmospheric or ferrostatic pressure, 3) characteristics of the molding material, and 4) size, shape, location and thermal treatment of gates and risers. In many cases the heterogeneous expansion resulting from graphite precipitation accentuates, rather than minimizes, solidification shrinkage.

A discussion is presented of the basic principles on which gray iron risering is based. A series of castings shown illustrate how these principles apply to the practical risering of gray iron castings.

INTRODUCTION

This paper presents detailed conclusions resulting from eight years research in the M.I.T. Foundry Laboratory on solidification and risering gray iron castings. Over five of these eight years were under sponsorship and guidance of the Research Committee of the Gray Iron Division, AFS. Added financial aid came from the International Nickel Company. The last three years work was sponsored entirely by the International Nickel Company.

It is not the purpose of this paper simply to rephrase the findings contained in the six progress reports.[1-6] These are already in the hands of the membership. It is the purpose here to present a definitive expression of the current state of knowledge concerning fundamental variables in solidification and risering of gray cast iron. Results obtained stem chiefly from direct experimentation. They reflect, as well, some recent contributions to the literature, (on the thermodynamics of the iron-carbon-silicon system) and concurrent studies of solidification and heat transfer (in metals other than cast iron). These studies have constituted part of the foundry research program at M.I.T. for the last several years.

As should be expected, statements contained in recent interim reports indicate some revision of opinions formed earlier in the research program. It is partly the function of this summary paper to resolve any confusion which might arise from previous papers and to present under one cover all significant valid conclusions and data considered consistent with experimental observations. For the convenience of the reader, the following section of the report is a summary of these conclusions. Detailed supporting material is then contained in following sections or in the Appendix.

SUMMARY OF CONCLUSIONS

After developing an annotated bibliography,[1] the first active step in the research program was an attempted analysis of castings. These castings were produced and supplied through cooperation of the Gating and Risering Committee of the AFS.[2] The conclusions formed during this phase were largely negative, but helped set the stage for the program which was to follow. These initial conclusions (A, B, and C) are still considered valid. They pertain to gray irons within the following composition range: More than 2.8 per cent carbon, 1-3 per cent silicon, less than 1.5 per cent manganese, 0.02-0.5 per cent sulphur, 0.02-0.6 per cent phosphorus.

Conclusion A

Gross localized shrinkage porosity may occur in almost any commercial gray iron cast into conventional green-sand molds. The location, magnitude and incidence of such porosity is variable, even when metal and molding conditions are substantially constant. The incidence of gross porosity is greatly reduced (frequently eliminated entirely) by use of an air- or oven-dried, clay-bonded sand, or by use of core-sand molds.

Conclusion B

Large conventional risers (similar to those used for steel) are expensive, and ineffective in solving many green-sand shrinkage problems. In some instances, risers apparently aggravate shrinkage. In a dry-sand mold, a small riser or just a gate usually produces a sound casting.

Conclusion C

Green-sand castings are more dimensionally variable than dry-sand castings. There is a pronounced tend-

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ency for certain sections of green-sand castings to be over-sized.

The three conclusions above constitute a fairly complete statement of the risering problem. Subsequent research has been aimed at testing hypothetical explanations of the erratic shrinkage behavior of cast iron. For example, it was felt some of the difference between green and dry sand might be attributed to the presence or absence of mold gases. One reasonably extensive phase of the research work involved studies of shrinkage behavior and densities of irons cast in green- or dry-sand molds. In these studies various gases bubbled through the metal prior to casting. From this was deduced the following conclusions.

Conclusion D

No evidence has been found to suggest that microporosity (invisible to the naked eye) has an important bearing on shrinkage behavior. It is known some alloy systems exhibit microporosity related to evolution of dissolved gases. In such systems (aluminum- or copper-base alloys), the density of cast metal, which appears macroscopically sound, may be lowered by the presence of microporosity.

This behavior has not been observed in gray iron. In gray iron the density of an apparently sound section varies only with composition, and it is not normally influenced by the presence of dissolved gases, even when solidified under reduced pressure (Fig. 1). Hydrogen (from water vapor) can, however, produce large scale porosity easily visible and of distinctly different morphology from shrinkage.

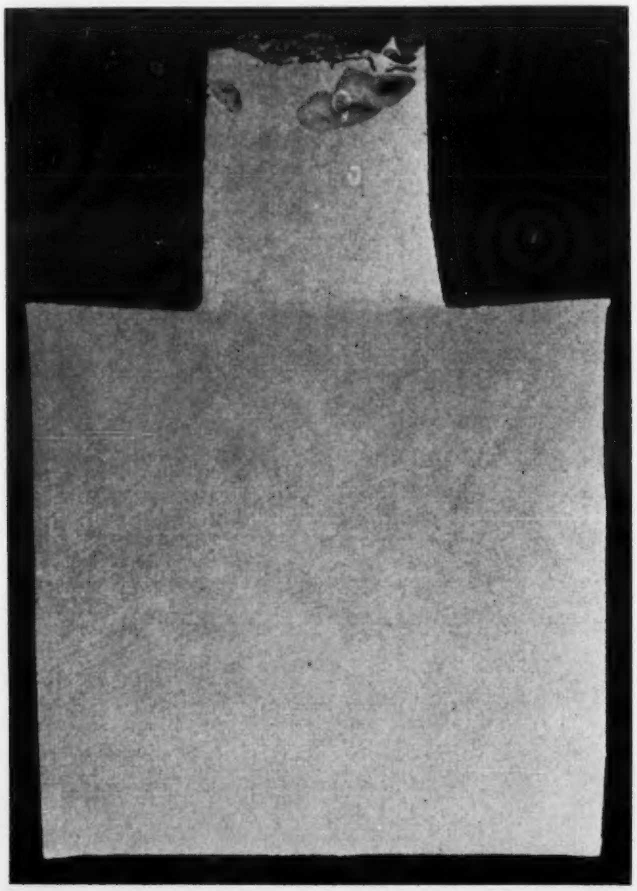

Fig. 1 — Photograph of a section of a 5 in. gray-iron cube solidified under reduced pressure. Pressure during solidification—less than 1 cm of mercury.

Since the density of the void-free metal was not found to vary with casting conditions, there seemed to be hope for conducting rigorous book-keeping on volume changes which accompany solidification of cast iron. Two pieces of apparatus were developed to observe volume changes during solidification of test castings.[3,4,5]

Conclusion E

Material balances have been derived which relate volume changes during solidification to carbon and silicon contents. The constants involved in these relationships have been selected or estimated as judiciously as possible from data in the literature or from measurements made at M.I.T. Agreement between predicted and measured values of shrinkage has generally been found within experimental error. Volume changes have been further linked to heat-flow analyses permitting comparison of measured and theoretical curves of shrinkage vs time.

Of course, a material balance can only permit prediction of total volume changes. It sheds no light upon geometric distribution of these volume changes throughout a particular casting. At this point certain questions might be raised: 1) What causes green-sand castings to exhibit dilation during solidification? Is dilation simply a consequence of heat and ferrostatic pressure acting to exceed mold strength, or is an internal, metallurgical push (associated with graphite precipitation) involved? 2) If dilation has a metallurgical origin, does it vary with graphite structure? Do alloying elements or impurities influence the tendency toward dilation? Research partly answered these questions.

Conclusion F

The evidence strongly suggests that a powerful expansive force occurs during solidification of gray iron. This force is related at least indirectly to graphite structure. Dimensional growth of green-sand castings during solidification is, somewhat paradoxically, associated with increased feeding requirements and shrinkage tendencies. Alloying elements which influence graphite structure also influence dilation and shrinkage.

Since the practical objective of the research has not been solely to collect fundamental information, but primarily to rationalize the risering problem, every effort has been made to bring the data into a practical focus. The most important conclusions concern the essential nature of the risering requirements of irons cast in green- and dry-sand molds. These are summarized below.

Conclusion G

Irons cast in dry-sand molds require little or no risering. The riser need remain liquid only during the proeutectic stages of cooling and solidification (until the casting is about 20 per cent solid). After this feeding is no longer required. An adequate riser may (and should) be quite small, but carefully positioned. Eutectic or hypereutectic irons cast in dry sand generally require no risering.

Conclusion H

Green-sand castings require a much greater volume of feed metal at a later stage in solidification than do dry-sand castings. The greatest demand for feed metal occurs while appreciable graphite precipitation is taking place near the surface of a casting. This causes the partially solid walls of the casting to expand and buckle. The buckling is usually outward, and increases the volume of the casting cavity. In certain instances the buckling and associated demand for feed metal may be sudden. The exact mechanics of this phenomenon are not easy to appreciate, and may frequently involve abrupt yielding of the mold wall.

Conclusion I

Large risers are frequently ineffective for feeding hypoeutectic irons cast in green sand. These irons freeze over large temperature intervals. During late stages of casting solidification a large riser may be too mushy to function properly. The large riser may complicate and exaggerate the thermal problem. It is necessary to isolate such risers, thermally, from the casting. A temperature difference of 100 F or greater should be maintained between the riser and the casting during solidification. Small, externally heated or well-insulated risers have been found remarkably effective. In effect, this principle has been utilized in measuring shrinkages of various irons.[5,6,7]

DISTRIBUTION OF SHRINKAGE IN GRAY IRON CASTINGS

A gray-iron casting which solidifies in a sand mold experiences a natural reduction in volume dependent on composition and pouring temperature. This shrinkage has been measured and evaluated,[5,6] and detailed results are presented in the following section. The actual size and location of the void which results, either in the casting or in the riser, depends upon factors influencing movement of the casting surface. These factors are: 1) The size and shape of the casting, 2) the action of atmospheric or ferrostatic pressure, 3) the characteristics of the molding material, and 4) the size, shape, location and thermal treatment of gates and risers.

The paradox of gray iron is that heterogeneous expansion accompanying precipitation of graphite is even more likely to produce a shrink cavity than is solidification shrinkage. Most irons exhibit little total true shrinkage, and that occurs least harmfully during the first stages of solidification (before the casting is twenty per cent solid).

Graphite precipitation, late in the solidification process, may have either or both of two effects: 1) Isotropic expansion may help feed the casting, a benefit widely recognized, but frequently fickle; and 2) local expansion may cause the exterior layers of a casting to expand and buckle outward. This creates a late, large, and sudden demand for feed metal.

Circumstances affecting this complicated behavior are not perfectly understood. The general behavior pattern is quite clear. The plasticity or rigidity of the molding material is of paramount importance. For example, Fig. 2A is a schematic cross-section of a simple, unrisered cylinder of gray iron cast into an oven-dried, bentonite-bonded synthetic sand mold. The exposed top surface has been insulated with rice hulls, and the resulting casting is quite sound.

The shrinkage, generally less than one per cent, was reported as a slight dishing of the insulated surface. Any tendency toward piping or internal shrinkage is absent, because all of the gross volume change has occurred during the early stages of solidification while the casting was more than 80 per cent liquid. Any tendency for outward buckling of the casting surface has been successfully resisted by the rigid mold. The same casting, produced in green synthetic sand, is shown in Fig. 2B. Here the casting surface has bulged slightly and gross internal shrinkage is the result.

The soundness and external dimensions of an iron casting produced in green sand may be influenced by the action of atmospheric pressure, and the directionality of solidification. The casting shown in Fig. 2B, produced in green sand with no top insulation may be perfectly sound, as shown in Fig. 2C.

The top of the casting solidified because of radiation heat loss to the surroundings. When the wall of the casting buckled, it kept the contained volume constant. In a casting which has been sealed in this way, atmospheric pressure resists any net expansion due to wall movement. The actual measured contours of such castings have been exaggerated for clarity.

The situation in Fig. 2C may actually be affected deleteriously by use of a large riser, with a result as shown in Fig. 2D. Here the riser has had the effect of eliminating any pressure difference tending to confine wall movement by keeping the system open, as did the insulation in Fig. 2B. Part of the demand imposed by wall buckling was so late the riser contained insufficient liquid feed metal.

In addition, the riser itself undergoes, dilation, adding to the demand almost as much as to the supply of feed metal. By contrast, a small riser can easily feed the early, slight demand of the dry-sand casting as shown in Fig. 2E.

Some of the phenomena, exaggerated in the various parts of Fig. 2, can be observed on actual castings shown in Fig. 3. Profile measurements, supporting the

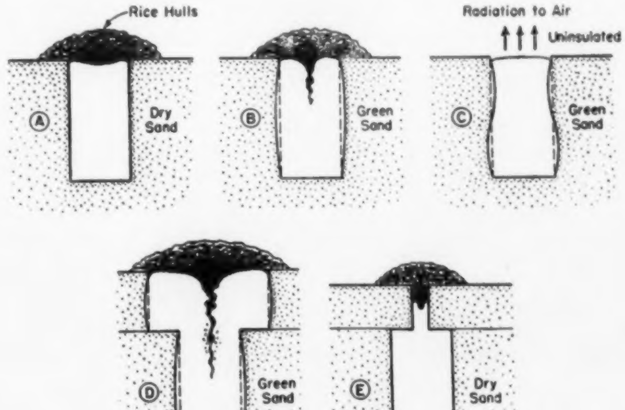

Fig. 2 – Schematic cross-sections of gray iron cylinder solidified under various molding and risering conditions.

configurational behavior set forth in Fig. 2, are shown in Fig. 4 and 5.

Most of the work on shrinkage has been done on cylinders and spheres. In these shapes buckling is outward and, therefore, harmful. The surface layers of a large flat plate can, on the other hand, buckle inward almost as easily as outward. Here, shrinkage is less of a problem. Extensive plate-like sections in gray iron are frequently sound. That is, except in regions of gates, risers or other discontinuities which either interfere with wall movement, negate the beneficial effect of atmospheric pressure, or delay solidification locally.

There is some evidence that large ferrostatic pressures achieved through tall gates, risers, or pop-offs, can encourage dilation to occur earlier in the solidification process while feed metal is still available. In other cases pressure appears to encourage outward rather than inward buckling and does more harm than good. The forces involved in dilation are large enough that ferrostatic pressure is not of great importance.

Following is an example to help gain an appreciation of the volumetric importance of dilation. A typical iron containing 3.4 per cent carbon and 2.1 per cent silicon is cast into a cylindrical mold cavity, nominally 3.75 in. diameter and 8 in. tall. The observation of dozens of such castings[4,5] has indicated a typical average (top, middle and bottom) difference in diameter of 0.05 in. between green- and dry-sand castings. Green sand castings being the larger (Fig. 4, 5), local differences may be much larger in some cases. This represents 1-1/3-per cent net dilation in terms of diameter, and 2-2/3-per cent in terms of volume (the casting does not dilate longitudinally) The iron itself only shrinks 1/3-per cent, but the total feed metal requirement is 3 per cent.

The 2-2/3 per cent excess feed metal requirement due to dilation is shown schematically in Fig. 6. Here, dilation is shown to scale. The resulting feed metal requirement is represented by a 1.65 in. diameter spherical hole shown in the center of the section. It almost seems impossible such a slight surface dilation could actually represent 2.35 cu in. of feed demand, or shrinkage as the case may be.

It is neither easy nor necessary to exaggerate the effect of dilation. Figure 6 summarizes the typical case and is by no means extreme. Quantitative shrinkage measurements on this casting have regularly indicated observed apparent total shrinkage of less than 1 per cent in dry sand and more than 3 per cent in green sand.

The dilation of iron castings is related to a metallurgical push, and cannot be explained in terms of heat and ferrostatic pressure alone. In work with tin bronze it was found that the surface temperature of a tin bronze casting is as high as that of a geometrically identical gray iron casting throughout most of the solidification process. The density of tin bronze is higher, and the time required for the surface layer to solidify is as long. Yet the difference in shrinkage between green- and dry-sand bronze cylinders is only about 1/2 per cent.[6] In other words, in spite of greater density, and equal temperature, the mold wall does not move with bronze but does with iron.

It should be repeated and emphasized that the serious feature of dilation is the timing even more

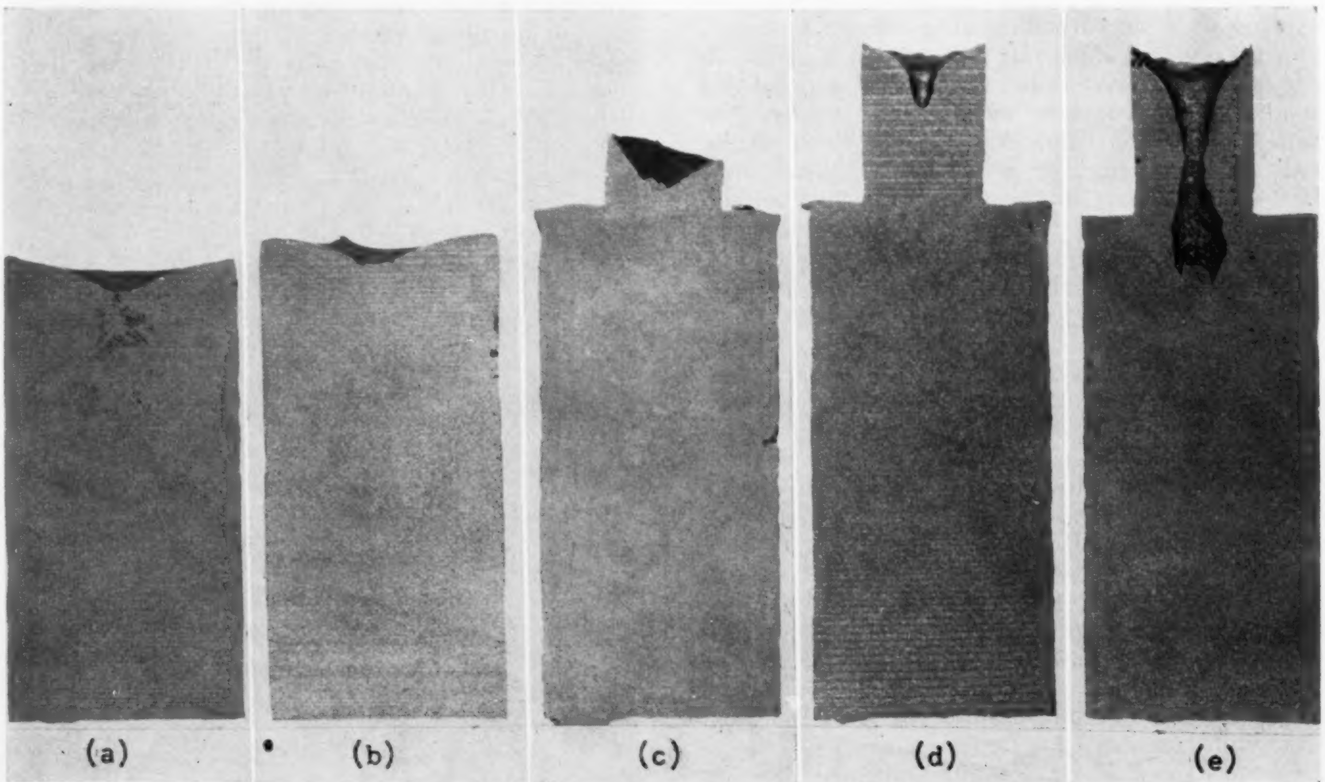

Fig. 3 — Cross-sections of gray iron cylinders solidified under various molding and risering conditions.
(a) Green sand, no riser, covered with rice hulls.
(b) Green sand, no riser.
(c) Green sand, insulated riser.
(d) Dry sand, conventional riser.
(e) Green sand, conventional riser.

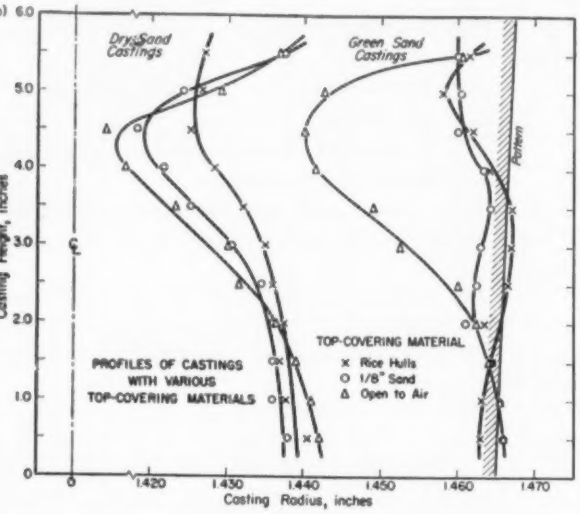

Fig. 4.

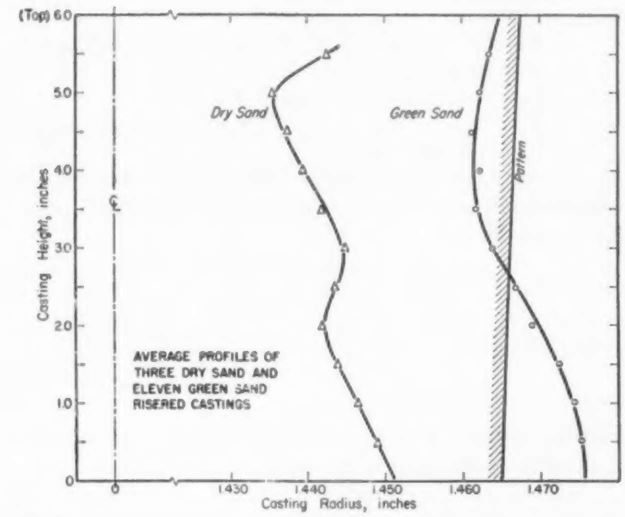

Fig. 5.

than the amount. Depending upon geometric and thermal environmental factors, that portion of dilation which creates a feed metal demand will generally occur after the true shrinkage has been successfully accommodated. Not only will the demand be much larger but may be quite rapid, even abrupt, at a time when limited remaining liquid metal may have a rather tortuous interdendritic flow path to the critical region.

VOLUME CHANGES IN GRAY IRON DURING SOLIDIFICATION

During this research, many measurements have been made at M.I.T. of the true shrinkage which accompanies the cooling and freezing of graphitic cast irons. The results are contained in the published reports.[4,5,6] Complete study of this experimental information coupled with data selected from the literature has permitted a fundamental correlation which is theoretically sound and in agreement with the experimental measurements.

It has been observed that considerable disparity exists among published basic data on iron-carbon-silicon alloys. In the following analysis, where it has been necessary and convenient to make a choice from differing available values, the decision has been predicated on agreement with experiment. This procedure has led to development of a list of what appear to be most correct critical physical constants relating to the solidification of gray cast iron. The list is presented in Table 1.

The Iron-Carbon-Silicon System

The representative sections of the iron-carbon-silicon ternary equilibrium diagram as presented by Piwowarski[8] correspond more closely with interpreted shinkage observations than those of any other source. The information required of these ternary sections can be expressed quite adequately for hypoeutectic irons by the following equations.

$$Y = 4.3 - 0.33\,(\%\ \text{Si}) - \frac{T - T_e}{260} \qquad (1)$$

$$\frac{X}{Y} = 0.5\ (\text{Piwowarski}^8) \qquad (2)$$

TABLE 1 – VALUES OF CONSTANTS USED IN SOLIDIFICATION CALCULATIONS

1. Slope of liquidus in F-C-Si alloys over the range 3.0 to 4.3 per cent Carbon Equivalent (0 to 4.0 per cent silicon). From Piwowarski[8]	260 F/%C
2. Heat of fusion of iron (austenite) at 2100F. From Darkin and Gurry[10]	106 BTU/lb
3. Specific heat of liquid iron and liquid iron –austenite mixture between 2100F and 2500F. From Kelly[11]	0.20 BTU/lb F
4. Average density of solid cast iron at 2100F. From M.I.T. Shrinkage Measurements[1-6]	440 lb/ft.$^{-3}$
5. Ratio of density of austenite to graphite at 2100F. From M.I.T. Shrinkage Measurements[1-6]	3.26
6. Ratio of density of liquid iron to austenite (at the same temperature). From M.I.T. Shrinkage Measurements[1-6]	0.961
7. Coefficient of thermal expansion of liquid iron and liquid iron–austenite mixture between 2100F and 2500F. From M.I.T. Shrinkage Measurements[1-6]	16.5 x 10^{-6} F^{-1}

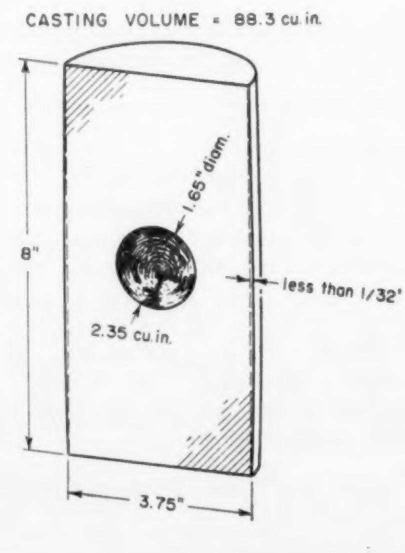

Fig. 6 – Schematic representation of a void generated by mold wall dilation.

where:

Y = %C in the liquid phase during solidification
T = temperature, F
T_e = eutectic temperature, F
X = %C in the solid phase (austenite) during solidification.

At the eutectic temperature, just before the eutectic reaction starts, the carbon content of the liquid phase, Y_e, is given by:

$$Y_e = 4.3 - 0.33\,(\%Si) \qquad (3)$$

Graphite is formed during the eutectic reaction and constitutes a small weight fraction, F_g, of the eutectic material:

$$F_g = \frac{1}{200/Y_e - 1} \qquad (4)$$

During formation of primary austenite, the fraction, f, of the metal which is solid is given by:

$$f = 2\,(1 - \frac{\%C}{Y}) \qquad (5)$$

At the eutectic temperature, just before the eutectic reaction starts, the fraction, f_e, of the metal which is solid is:

$$f_e = 2\,(1 - \frac{\%C}{Y_e}) \qquad (6)$$

Volume Changes During Solidification

Practically all of the volume change which occurs during solidification of gray iron precedes the eutectic reaction. At any moment during primary austenite formation, the fractional shrinkage, β', which has taken place is given by:

$$\beta' = f\beta + \alpha\,(T_p - T) - f\beta\alpha\,(T_p - T) \qquad (7)$$

Since the third term in Equation (7) is negligibly small:

$$\beta' = f\beta + \alpha\,(T_p - T) \qquad (7A)$$

where:

T_p = pouring temperature
T = temperature at which f fraction of the casting is solid austenite

$$\beta' = \frac{\text{original liquid–volume of partly solid casting}}{\text{original liquid volume}}$$

α = observed average coefficient of volumetric thermal contraction for liquid iron and for austenite-liquid mixtures
β = unit fractional shrinkage characteristic of the solidification of austenite.

(i.e., $\beta = 1 - \frac{\rho\lambda}{\rho\gamma}$)

where:

$\rho\lambda$ = density of liquid
$\rho\gamma$ = density of austenite.

At the eutectic temperature, just before the eutectic reaction starts, the shrinkage which has occurred, β_p, is referred to as "primary shrinkage" and is given by:

$$\beta_p = f_e\beta + \alpha\,(T_p - T_e) \qquad (8)$$

During the eutectic reaction an additional volume change takes place. The total fractional shrinkage, β_e, which results from the complete eutectic reaction can be estimated from:

$$\frac{\beta_e}{1 - f_e} = \beta - F_g\,(1 - \beta)\left(\frac{\rho\gamma}{\rho_G} - 1\right) \qquad (9)$$

Again, second order terms have been neglected.
where:

$$\beta_e = \frac{\text{volume decrease accompanying the eutectic reaction}}{\text{original liquid volume of the casting}}$$

ρ_G = density of graphite.

β_e is usually quite small and negative which means a slight expansion usually occurs during the eutectic reaction.

From the moment of pouring to the instant solidification becomes complete at the eutectic temperature, the total fractional shrinkage, β_T, which has occurred is given by:

$$\beta_T = \beta_p + \beta_e \qquad (10)$$

where:

$$\beta_T = \frac{\text{original liquid volume–hot solid volume}}{\text{original liquid volume}}$$

The three values, β_p, β_T and β_e are nearly linear functions of pouring temperature, %C and %Si, over the range of interest, so that Equations (8), (9) and (10) can be closely approximated by:

$$100\beta_p = \frac{16.5\,(T - T_e)}{1{,}000{,}000} + 8.27 - 1.95\,(\%C) - 0.53\,(\%Si) \qquad (11)$$

$$100\beta_e = 0.35 - 0.26\,(\%C) + 0.17\,(\%Si) \qquad (12)$$

$$100\beta_T = \frac{16.5\,(T - T_e)}{1{,}000{,}000} + 8.62 - 2.21\,(\%C) - 0.36\,(\%Si) \qquad (13)$$

where: $100\beta_p$, $100\beta_e$, and $100\beta_T$ are percent shrinkages.

The Heat Evolved During Solidification

During primary separation of austenite from the liquid, the total heat, Q, which has been evolved by the time f fraction of the casting is solid is calculated from:

$$\frac{Q}{M} = C_p\,(T_p - T) + f\,H \qquad (14)$$

where:

M = weight of casting
C_p = specific heat of liquid iron and of austenite-liquid mixtures.

The total heat, Q_T, which must be evolved from the moment of pouring for the casting to become completely solid at the eutectic temperature is:

$$\frac{Q_T}{M} = C_p\,(T_p - T_e) + H \qquad (15)$$

The Rate of Solidification

The time, θ, required for a certain amount of heat to leave a sand casting and enter the mold depends on the volume, V, and heat-abstracting surface area, A, of the casting as well as the original temperature, T_o, and thermal properties of the sand, and the average effective surface temperature, T_S, of the casting during the time interval in question. To a lesser extent the time required is also dependent on the shape of the casting. For a simple slab of indefinite extent:

$$\sqrt{\theta} = 168.5\,\frac{\left(\frac{V}{A}\right)\left(\frac{Q}{M}\right)}{(T_S - T_o)} \qquad (16)$$

In Equation (16) the constant, 168.5, is dimensional and requires that dimensions be expressed in in., heat

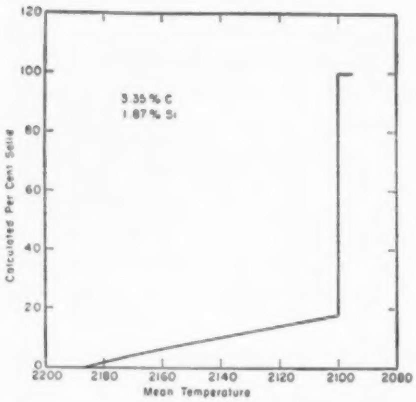

Fig. 7 — Calculated per cent solid vs mean temperature during cooling of a typical hypoeutectic gray iron.

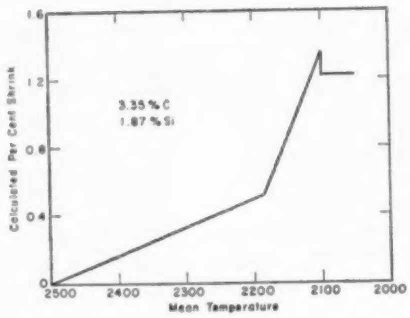

Fig. 8 — Calculated per cent shrink vs mean temperature during cooling of a typical hypoeutectic gray iron.

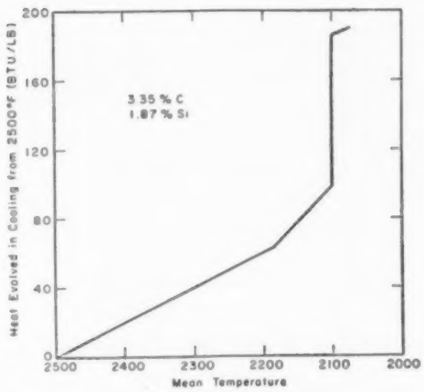

Fig. 9 — Heat evolved in cooling a typical hypoeutectic gray iron from 2500F.

in BTU, weight in lb, temperature in degrees F, and time in min. In particular, the constant, 168.5, is valid for oil-bonded core sand of no. 80 AFS fineness number. The thermal properties of molding sands vary little enough that Equation (16) applies generally to gray iron sand castings. Equation (16) applies with fair accuracy to that important category of gray-iron castings which can be construed as plates bent into various shapes. An example is a hollow cylinder whose wall thickness is small compared to its diameter.

However, heat flow from shapes like bars, spheres, cubes or other three dimensional chunks is somewhat divergent and, therefore, more rapid than from plates. Analyses and measurements on simple shapes (cylinders and spheres) show that heat flow from gray iron into sand conforms closely to the equation:

$$\sqrt{\theta} = 168.5\left(\frac{\frac{V}{A}}{T_S - T_o}\right)\left(\frac{\frac{Q}{M}}{1+\sqrt{1+\frac{Q/M}{146.8}}}\right) \quad (17)$$

Equations (16) and (17) are founded on heat conduction relationships set forth in another paper.[9] The constants are based on thermal analyses (experimental) of gray iron castings. The value of T_S changes somewhat during the course of solidification, starting as high as 2400 F and finishing somewhat below 2100 F. For precise determination of a cooling curve this variation may be taken into account. To calculate the time required for complete solidification TS may be taken as equal to 2100F.

Shrinkage Behavior of a Typical Gray Iron

Some of the quantitative relationships set forth in preceding paragraphs are illustrated graphically in Fig. 8-13 for an iron casting containing 3.35 per cent C and 1.87 per cent Si, having the dimensions shown in Fig. 7, and poured at 2500 F. Detailed consideration of this single casting provides a framework for unambiguous description of the solidification and shrinkage pattern of any hypoeutectic cast iron. In addition, experimental data on this alloy permit a point-by-point comparison of observed and theoretical shrinkage histories.

Figure 7 shows the per cent of the casting which is solid as a function of the mean or average temperature of the casting. Figure 7 has been plotted from Equations (1) and (5), and indicates the metal starts to freeze at 2186 F, and is 18 per cent solid when the eutectic temperature is reached. The rest of the alloy freezes isothermally. (Although in principle the austenite-graphite-liquid equilibrium can exist over a range of temperature, a distinct eutectic temperature is assumed in this discussion. Piwowarski[8] indicates the eutectic band is in fact quite narrow).

In Fig. 8 cumulative per cent shrink computed from Fig. 3 and Equations (3), (4), (6), (7) and (9) is plotted vs mean temperature. From 2500 F (the pouring temperature) to 2186 F, liquid contraction occurs. Between 2186 F and the eutectic temperature liquid contraction and solidification shrinkage take place simultaneously. The total primary shrinkage is 1.36 per cent. At the eutectic temperature a slight (0.14 per cent) expansion accompanies solidification of over 80 per cent of the casting. The net shrinkage is 1.22 per cent.

Since one of the objectives is to evolve a theoretical shrinkage vs time curve, some knowledge of heat evo-

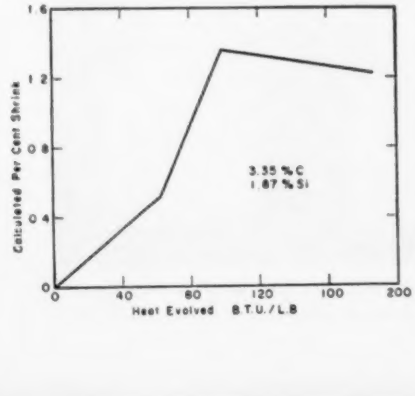

Fig. 10 — Calculated per cent shrink vs heat evolved for a typical hypoeutectic gray iron.

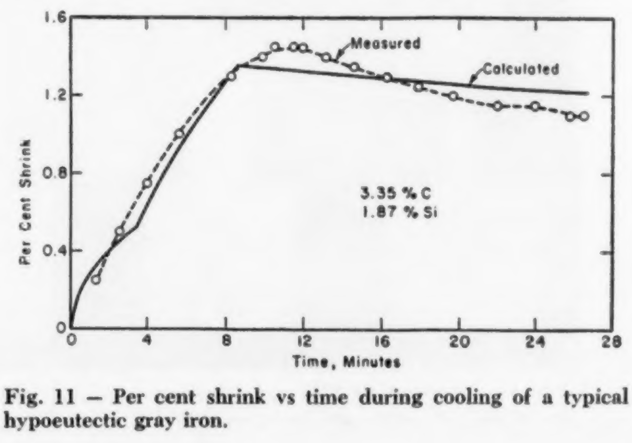

Fig. 11 — Per cent shrink vs time during cooling of a typical hypoeutectic gray iron.

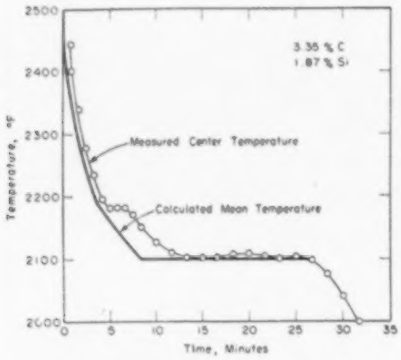

Fig. 12 – Temperature vs time during cooling of a typical hypoeutectic gray iron.

lution in terms of temperature and shrinkage is required. These variables can, in turn, be related to time using heat flow relationships. In Fig. 9, the cumulative heat evolved per lb of metal is plotted against mean temperature, using previous figures and Equations (14) and (15).

It may be seen that heat evolution starts at the pouring temperature, and increases with the beginning of solidification at 1826 F. A large amount of heat is evolved at the eutectic temperature. Slightly more than half the heat removed during solidification is heat of fusion. The rest is specific heat of cooling from 2500 F to the eutectic temperature.

Figures 8 and 9 have been used to prepare Fig. 10. In Fig. 10 the per cent shrink as a function of heat evolved is shown. The first discontinuity in the graph of Fig. 10 reflects a change when the liquidus temperature is reached, the second when the eutectic temperature is reached.

Using Fig. 10 and Equation (17) the desired plot of shrinkage vs time can be obtained. This is shown in Fig. 11 where close agreement with a measured shrinkage-time curve is evident. The sharp discontinuities in the computed curve are not physically realistic since cooling and freezing of the metal is not perfectly uniform. Events near the surface of the casting somewhat precede those in the center. The important observation, whether theoretical or experimental, is that the slight shrinkage of most gray irons occurs in less than half the time required for complete solidification, and should not present much of a risering problem.

There is some interest in comparing calculated mean temperature with measured center temperature of the casting (Fig. 12). The center temperature may be expected to lag behind the mean temperature. The brief arrest at the liquidus temperature in the center of the casting manifests this lag. Shrinkage measurement is more of a bulk observation, characteristic of the entire casting. In a sense it integrates the cooling curves of all parts of the casting.

The general agreement of predicted with measured total shrinkage is a matter of record.[4,5,6] The preceding is a summarized, partly revised, and simplified expression of the dependency of true shrinkage on composition and pouring temperature. The dynamics of the volume changes in gray iron are generally exhibited by Fig. 7-12, even though the charts pertain quantitatively to a particular iron.

Behavior of Risers on Gray Iron Castings

The characteristic dimensional and volume changes which occur during solidification of gray iron castings are exemplified in Fig. 13-17. In these figures, cross-sections are shown of risered and unrisered castings

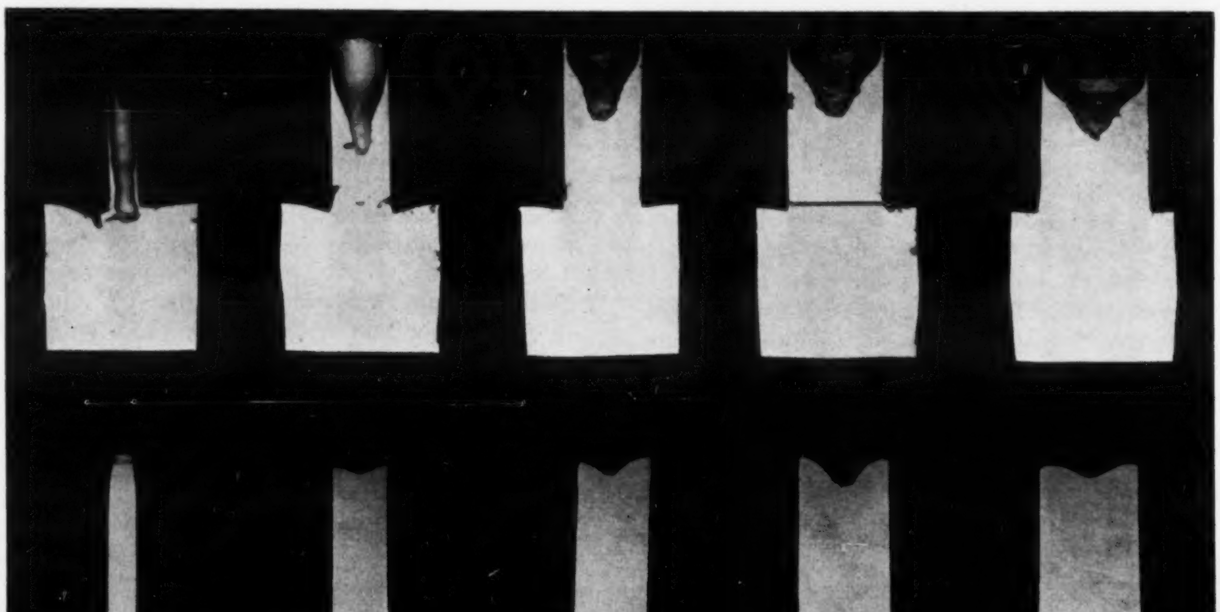

Fig. 13 – Sections of 5 in. gray iron cubes poured at 2450F. Cubes in top row were cast in green-sand molds; those in bottom row were cast in dry-sand molds. Riser diameters (left to right) are: 1 in., 2 in., 2-1/2 in., 3 in., and 3-1/2 in.

made in green and dry sand. All castings were of metal containing approximately 3.35 per cent carbon and 2.0 per cent silicon. Melting of the metal was by induction.

Examination of Fig. 13-17 reveals qualitatively the presence and distribution of shrinkage, gross changes in exterior contour (exudation and mold dilation), and the relative volume of feed metal required by the casting during solidification. The general pattern of behavior of gray iron during solidification previously discussed is illustrated and documented by these castings.

Figure 13 presents a series of cross-sections of 5 in. gray iron cubes, top risered with risers of diameters varying from 1 in. to 3-1/2-in. and poured at 2450 F into both green- and dry-sand molds. The castings poured in green-sand molds dilated severely. The amount of dilation tended to increase as the riser diameter increased (Fig. 13, top row).

These green sand castings required a relatively large amount of feed metal. The contour of the risers indicate that this demand was quite sudden and associated with mold dilation. The castings shown in the bottom row of Fig. 13 were poured in dry sand. The walls of these castings are relatively straight, indicating little or no mold dilation. Almost no pipe is apparent in any of the risers of the dry-sand-molded castings.

Figure 14 illustrates a series of castings similar to those of Fig. 13, except that the pouring temperature of these castings was 2650 F as compared to 2450 F for the previous series. The increase in pouring temperature did not significantly affect shrinkage in either the green- or dry-sand castings.

In Fig. 15, a series of sections are shown cut from 10 x 8 x 1.7 in. plates. The plates were cast in green and dry sand molds, unrisered and with 2, 3, and 4 in. diameter risers. The unrisered plate cast in green sand was essentially free of shrinkage or mold dilation. Addition of the 2 in. diameter riser resulted in sufficient mold dilation that the riser was depleted to the level of the casting. As a result, surface dishing occurred.

As the riser diameters of the green-sand-molded castings were increased, mold dilation became more severe, but the risers were adequate to feed the castings. These effects are illustrated in the left column of Fig. 15. Comparative castings poured in dry sand show relatively little pipe and essentially no mold dilation (Fig. 15, right-hand column).

In summary, Fig. 13, 14, and 15 illustrate that green- and dry-sand castings of any shape differ principally in that risered green-sand castings dilate observably, demand more feed metal, and require larger risers to guarantee soundness than do similar dry-sand castings. A riser for a dry-sand casting will generally feed the casting even though the riser may be so small that it solidifies long before the casting. This is because virtually all the true solidification shrinkage (of most gray irons) has occurred by the time the casting is 20 per cent solid. In green sand, the main feeding requirement is brought about by mold dilation and occurs long after true solidification shrinkage has ceased. Consequently, an adequate riser for a green-sand casting must remain liquid almost as long as the casting. It is the timing, not the amount of shrinkage, which occasions the need for large risers on green-sand castings.

Atmospheric pressure may have either a detrimental or a beneficial effect on the soundness of gray-iron castings. An undersize riser on a cube or other chunky shape, cast either in green or dry sand, may only serve to generate a hot spot. The hot spot then may

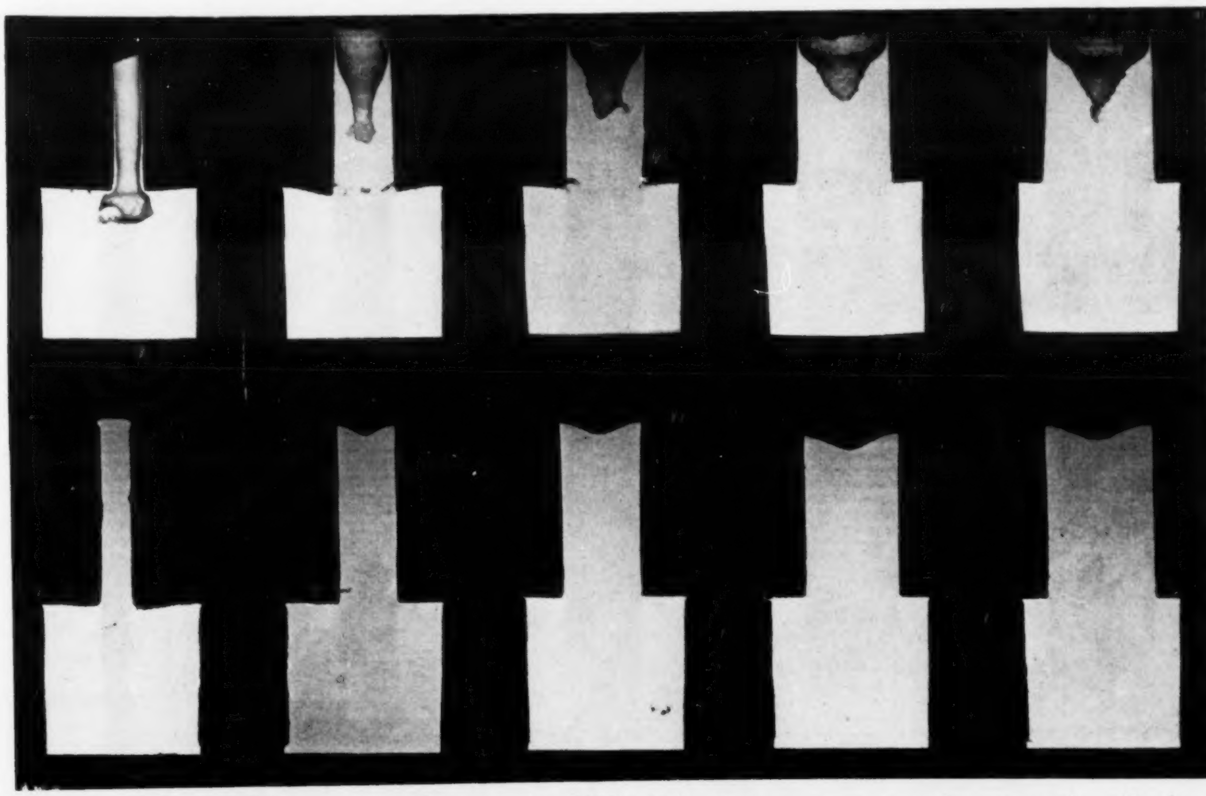

Fig. 14 – Sections of 5 in. gray iron cubes poured at 2650F. Cubes in top row were cast in green-sand molds; those in bottom row were cast in dry-sand molds. Riser diameters (left to right) are: 1 in., 2 in., 2-1/2 in., 3 in., and 3-1/2 in.

yield under the action of internal shrinkage (and mold dilation) and external atmospheric pressure, causing a local dishing on the casting surface.

This effect is clearly indicated in various castings of Fig. 13 and 14. In the absence of risers, atmospheric pressure may promote soundness by encouraging uniform distribution of contractual wall movement. That is, by distributing any dishing so broadly that it results only in a casting of slightly reduced over-all dimensions.

Atmospheric pressure may even promote soundness in unrisered green-sand castings, especially those of platelike configuration. This is done by distributing any contractual wall movement, and by minimizing mold dilation. When a small riser is added to such a casting, atmospheric pressure acts through this riser and equalizes the internal and external pressures. Mold dilation can then more readily occur with consequent gross shrinkage. In practice, a green-sand casting should either have no riser at all, or a riser adequate to feed a dilating casting. These effects are particularly evident in the green-sand casting cross-sections of Fig. 15, as well as in those of Fig. 3.

To circumvent the ill effects associated with a hot spot, it may sometimes be desirable to isolate the riser thermally from the casting. The feasibility of this procedure is represented in Fig. 16. A gray-iron riser can function through a remarkably small area of contact with the casting, partly because true shrinkage occurs early in the solidification process.

In addition, small contact permits establishment of a temperature difference between the riser and the casting. This is an effect of great importance in an alloy having a wide freezing range. In a metal like steel, for example, it is possible for the riser to be 90 per cent liquid at a time when the casting is only 40 per cent liquid without any appreciable temperature difference between the riser and the casting.

In gray iron this situation cannot occur. To be substantially more liquid, the riser must be at a higher temperature than the casting. Such a temperature difference cannot be maintained unless thermal contact between the riser and the casting is minimized.

To carry this line of thermal reasoning one step further, the maintenance of a favorable temperature difference between a small riser and a large casting can only be achieved by 1) minimizing riser-casting contact, and 2) insulating and/or adding heat to the riser. The judicious use of heated risers can accomplish feeding of heavy castings even in green sand without the problems (economic and physical) attendant to use of excessively large risers.

A casting fed by an exothermic riser is illustrated in Fig. 17. The principle of heated risers was employed in effect for all quantitative shrinkage measurements performed during this investigation.

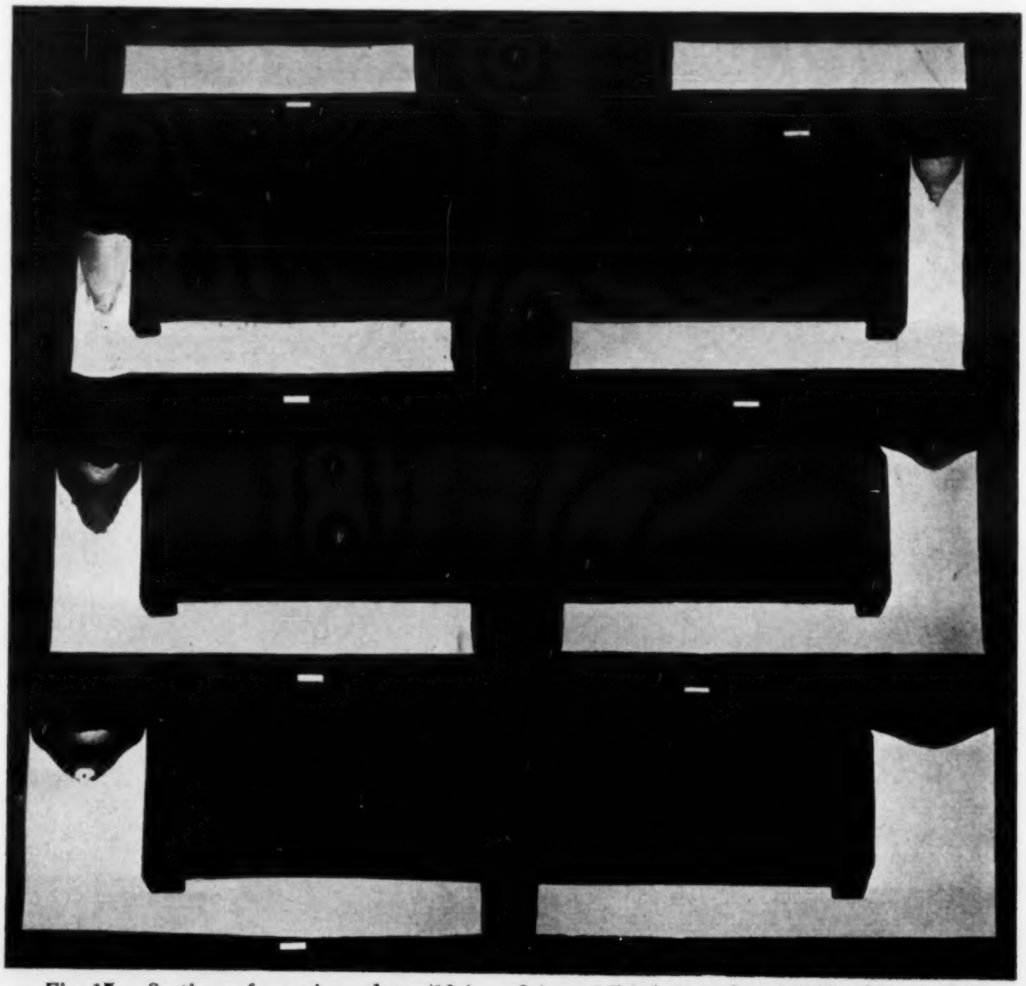

Fig. 15 – Sections of gray iron plates (10 in. x 8 in. x 1.7 in.) poured at 2650F. Plates in left column were cast in green-sand molds; those in right column were cast in dry-sand molds. Riser diameters (top to bottom) are: 0 in., 2 in., 3 in., and 4 in.

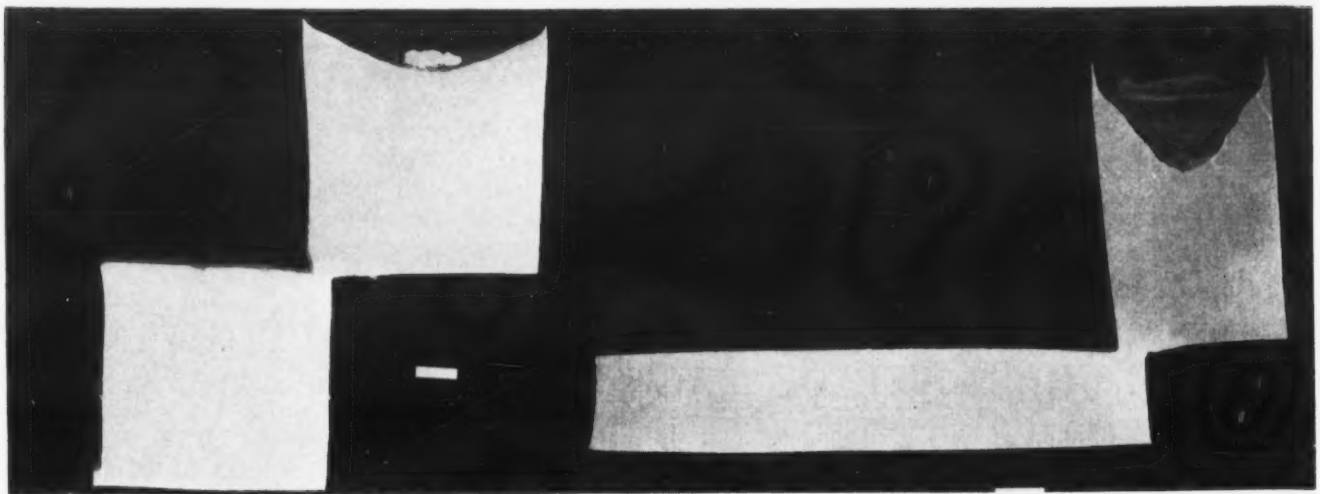

Fig. 16 – Photographs of sections of edge risered cube and plate. Pouring temperature 2650 F, green-sand molds. Left–5 in. cube; right–10 in. x 8 in. x 1-2/3-in. plate.

In conclusion, it should be noted that the problem of risering gray-iron castings is unique in that 1) apparent shrinkage is as much a mechanical as a thermal problem, and 2) the natural reduction in volume of gray iron during solidification, may be essentially complete when the metal is only 20 per cent solid. Subsequent solidification may actually result in a volume increase.

These characteristics are shared by no other cast metal. The importance of these characteristics in determining the risering requirements of gray cast iron is: procedures developed for dimensioning and locating risers of other metals must be modified to apply to gray iron risering. However, the basic mechanisms underlying the solidification of gray iron are now well enough understood that risering can be approached systematically, as it has been with other metals. Reliable and general procedures will certainly evolve, but these procedures must be based directly on the unique characteristics of gray cast iron solidification.

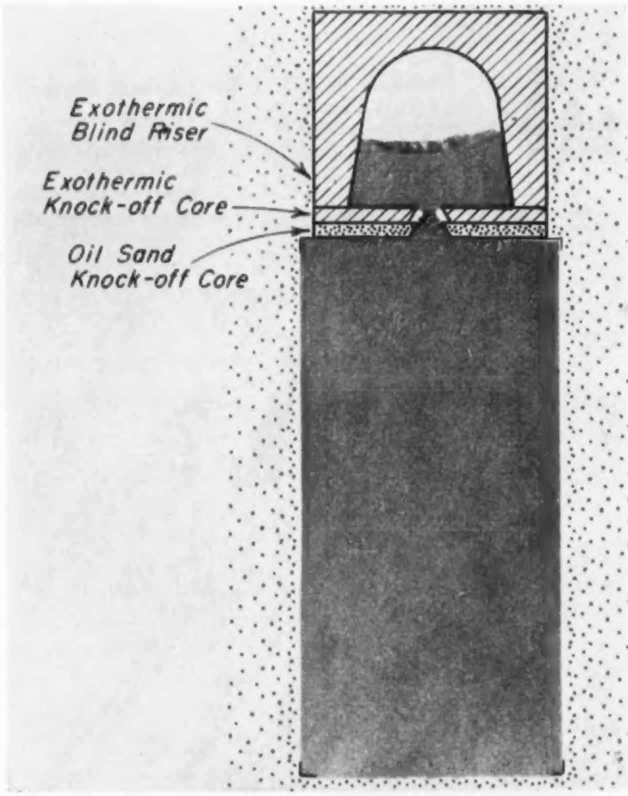

Fig. 17 – Photograph of a section of a gray-iron casting fed with an exothermically heated riser. Exothermic material and core inserts are sketched.

ACKNOWLEDGMENT

Over the eight-year period of this research many men have contributed importantly in one or another way. The authors are grateful to Charles C. Reynolds, William O. Schmidt, Paul F. Hughes, Edward Sullivan, George E. Schmidt, and Edwin Backman for their direct efforts in making this work possible. Appreciation is also acknowledged to the Gray Iron Division of AFS for their initial sponsorship and guidance, and in particular to James Vanick for his suggestions and continued enthusiasm. It would not have been possible to undertake the work in the beginning or to have completed it without the interest and financial support of Donald J. Reese and the International Nickel Company.

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THE EFFECT OF COOLING RATE ON THE GRAIN SIZE OF MAGNESIUM CASTING ALLOYS

By

R. D. Green*

ABSTRACT

A study of the effect of cooling rate on the grain size of several magnesium-aluminum-zinc alloys and a magnesium-rare earth-zinc alloy is presented. It is shown that the grain size of Mg-Al-Zn alloys is established at 50F (28 C) below the liquidus. For the case of the Mg-RE-Zn alloy the grain size is established at 30F (17C) below the liquidus. Correlation of grain size and cooling rate through the above ranges shows that in Mg-Al-Zn alloys the grain size decreases as the cooling rate increases to 200F/min, and then remains constant with further increases in cooling rate to 600F/min.

There is little effect of cooling rate on the grain size of the Mg-RE-Zn alloy. The effect of cooling rate on grain size is explained on the basis of constitutional supercooling and nuclei effectiveness.

INTRODUCTION

One of the methods of achieving a fine grain size and its resultant benefits in magnesium alloy castings is rapid freezing. This is readily achieved in die castings. In fairly heavy sections of permanent mold sand castings and in thin sections of sand castings, it is not so. The most readily adaptable method of increasing the cooling rate of sand castings is the insertion of chills into the mold. To make intelligent use of chills resulting cooling rates in fine grain size and temperature range through which the rates must be determined must be known.

In view of the long time for which the effect of cooling rate on grain size has been known, the results of an extensive literature search were rather disappointing. Despite the fact that it has been known for many years that rapid cooling usually results in fine grain size, little quantitative work has been done on the subject. This may be a case where accurate measurements were impossible to make when an effect was first noticed. Over the years the principle became so well known that when instruments were developed which would make accurate measurements possible, no one bothered to make any quantitative studies.

Perhaps the closest approach to the present work is that of Popov[1] who made an extensive study of the effect of casting temperature, cooling velocity, and layer thickness on the type of crystallization in several aluminum alloys. Hensel[2,3] mentions the effect of solidification time on the grain size of nickel silver and a 5 per cent tin bronze. Silvagni and Mondolfo[4] point out the difference in grain size of chill cast (solid in 5-10 sec) and sand cast (solid in 4-5 min) ternary aluminum base alloys.

Some work of a similar nature was that of Winkler[5] who studied the relationship between cooling velocity and crystal size of basaltic magma in dikes. The

TABLE 1 – NOMINAL COMPOSITION OF ALLOYS

Alloy	% Al	% Zn	% TRE*	% Mn	% Zr
AZ63A	5.3-6.7	2.5-3.5	....	0.15 Min.	....
AZ92A	8.3-9.7	1.6-2.4	....	0.10 Min.	....
AZ81A	7.0-8.1	0.4-1.0	....	0.13 Min.	....
EZ33A	......	2.0-3.5	2.5-4.0	....	0.5 Min.

* Total rare earth – added as mischmetal.

TABLE 2 – ANALYSES OF ALLOY COMPOSITION

Alloy	% Al	% Zn	% TRE*	% Mn	% Zr
AZ63A	6.2	3.01	....	0.25	....
AZ92A	9.1	2.08	....	0.19	....
AZ81A	8.0	0.73	....	0.22	....
EZ33A	....	3.10	2.92	....	0.64

* Total rare earth – added as mischmetal.

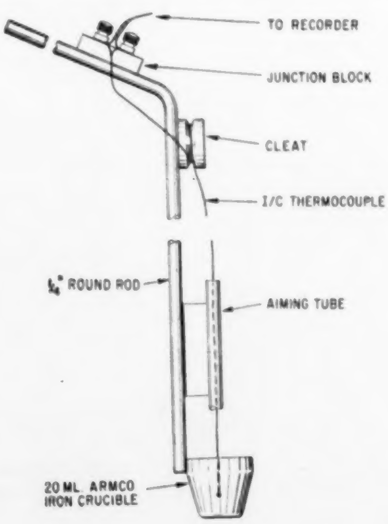

Fig. 1 – Apparatus used to obtain cooling range samples.

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similarity of phenomena occurring when magmas and when metals solidify had earlier been pointed out by Smith.[6] The effect of cooling rates through temperatures above the liquidus has also been investigated.[7] Although it can be shown that slow cooling rates in this range result in coarse grain size in superheated magnesium-aluminum-zinc alloys, the same effect is achieved by holding the melt at low temperatures. Slow cooling rates in the liquid range are equivalent to holding at low temperatures, and should not be misconstrued as being a true effect of the cooling rate on the grain size of these alloys.

PROCEDURE AND APPARATUS

The alloys studied in this work were AZ63A, AZ92A, AZ81A and EZ33A. The nominal composition of the alloys is listed in Table 1. The spectroscopic analysis of the composition of the alloys used is shown in Table 2.

The melts of the various alloys were prepared in clean steel crucibles using standard magnesium melting and alloying techniques. The magnesium-aluminum-zinc alloys were chlorinated at 1350F (732 C) and superheated at 1650F (899 C). These alloys were then allowed to cool to 1480F (804 C) for obtaining freezing range samples, or to 1450F (788 C) for pouring the castings from which cooling-rate specimens were obtained. The magnesium-rare earth-zinc alloy was flux refined at 1400F (760 C) after alloying.

Before cooling rates could be accurately determined, it was necessary to establish the temperature range

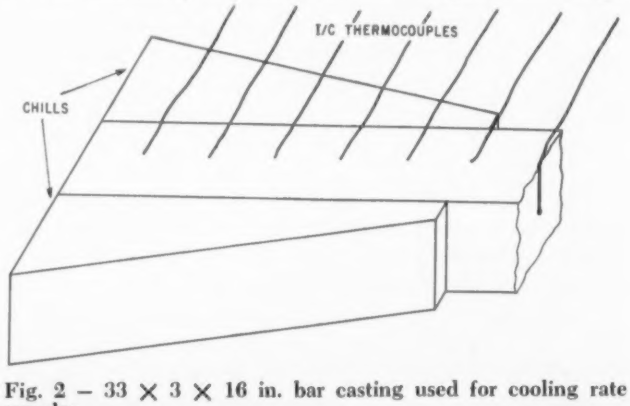

Fig. 2 – 33 × 3 × 16 in. bar casting used for cooling rate samples.

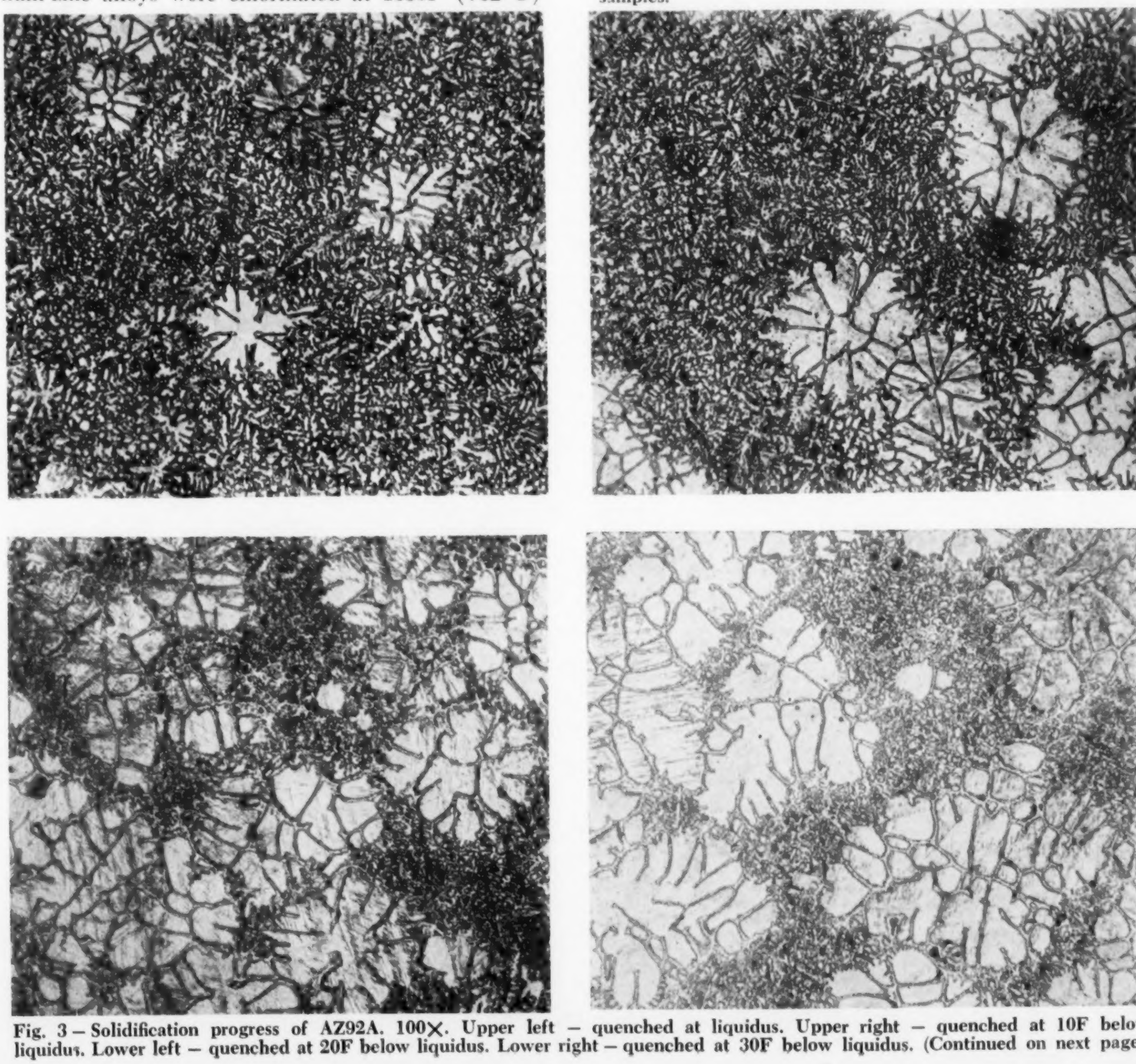

Fig. 3 – Solidification progress of AZ92A. 100×. Upper left – quenched at liquidus. Upper right – quenched at 10F below liquidus. Lower left – quenched at 20F below liquidus. Lower right – quenched at 30F below liquidus. **(Continued on next page.)**

through which cooling rates were effective. The apparatus used for obtaining freezing range samples is illustrated in Fig. 1. The crucible was immersed in the molten metal until it reached metal temperature and was then submerged to be filled with metal. The sample was then held in still air for cooling.

A glass insulated iron-constantan thermocouple was connected to a high speed recorder which was calibrated with a potentiometer before and after each run. The temperature drop was followed on the recorder. When the desired temperature below the liquidus was reached the sample was plunged into a bucket of cold water. The samples obtained in this manner were sectioned for metallographic examination.

The samples for correlation of cooling rate and grain size were taken from 3-in. x 3-in. x 16-in. bars which were chilled with steel chills arranged as shown in Fig. 2. Glass insulated iron-constantan thermocouples were placed every 2 in. along the casting centerline. Temperatures were recorded with a 16 point recording potentiometer which printed once each sec.

The thermocouples in the most heavily chilled locations were so connected as to print in 3 positions. The castings were sectioned so that each metallographic specimen contained a thermocouple bead.

The grain size of the specimens was measured by the comparison method. The as-cast grain size was determined and then the magnesium-aluminum-zinc alloys were solution heat treated and slightly aged. This treatment made the grain boundaries more discernible. Since there were few discrepancies in the grain sizes in the two conditions, the latter were considered more accurate and have been used as the correct results.

RESULTS AND DISCUSSION

Cooling Range

The amount of metal solidified at any temperature between the liquidus and solidus temperatures is not a linear function of Δ T (liquidus temperature minus the temperature under consideration). It is necessary to determine at what temperature below the liquidus the grain size is established before one can

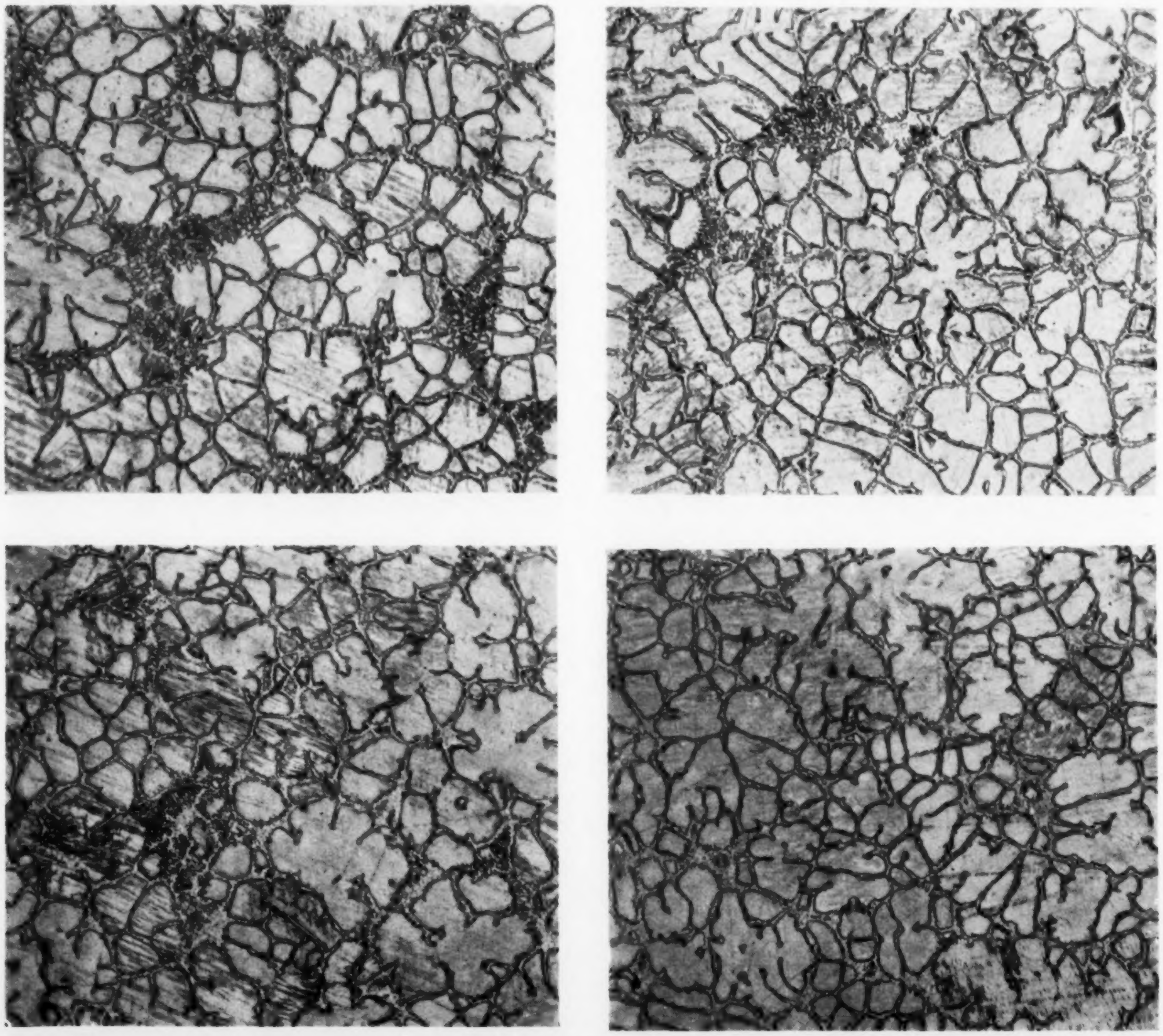

Fig. 3 (Continued) – Solidification progress of AZ92A. 100×. Upper left – quenched at 40F below liquidus. Upper right – quenched at 50F below liquidus. Lower left – quenched at 75F below liquidus. Lower right – quenched at 100F below liquidus.

investigate the effect of cooling rate on grain size. Previous work in this field was done using solidification time as a measure of cooling rate.[2,3,4]

Figure 3 illustrates the solidification progress of AZ92A which is typical of the magnesium-aluminum-zinc alloys, while Fig. 4 illustrates the same mechanism for EZ33A. An examination of the photomicrographs reveals that the grain size of the magnesium-aluminum-zinc alloys has been established when the metal has cooled to a temperature of 50F (28 C) below the liquidus. The equilibrium liquidus-solidus range for the various alloys is from 215-280F (120-156 C) and the nonequilibrium range is even greater.

In addition, cooling curves for AZ63A showed a definite break and an increase in slope at 50F (28 C) below the liquidus at various cooling rates. This indicates that the rate of release of latent heat of fusion had decreased due to a decrease in the rate of solidification. Analysis of the photomicrographs on a volumetric basis reveals that at 50F (28 C) below the liquidus 80 to 90 per cent of the metal is solid.

Thus, when the cooling rate of magnesium-aluminum-zinc alloys is mentioned hereafter, it will refer to the cooling rate from the liquidus to the liquidus minus 50F (28 C). Similarly, in the case of EZ33A the grain size is established at only 30F (17 C) below the liquidus, and this is the temperature range through which the cooling rate will be determined.

Correlation of Cooling Rate and Grain Size

As expected, slow cooling rates resulted in larger grains than did fast cooling rates. The effect of cooling rate on the grain size of chlorinated and superheated magnesium-aluminum-zinc alloys is shown in Fig. 5, 6 and 7. The three curves are similar in all respects. The average grain diameter decreases to 0.004 in. as the cooling rate increases to 200F/min. (111 C/min.).

Further increases in the cooling rate do not result in any reduction of grain size. It should not be assumed that a grain size of 0.004 in. is the smallest that can be achieved in magnesium-aluminum-zinc alloys. Average grain diameters of 0.001-0.002 in. are

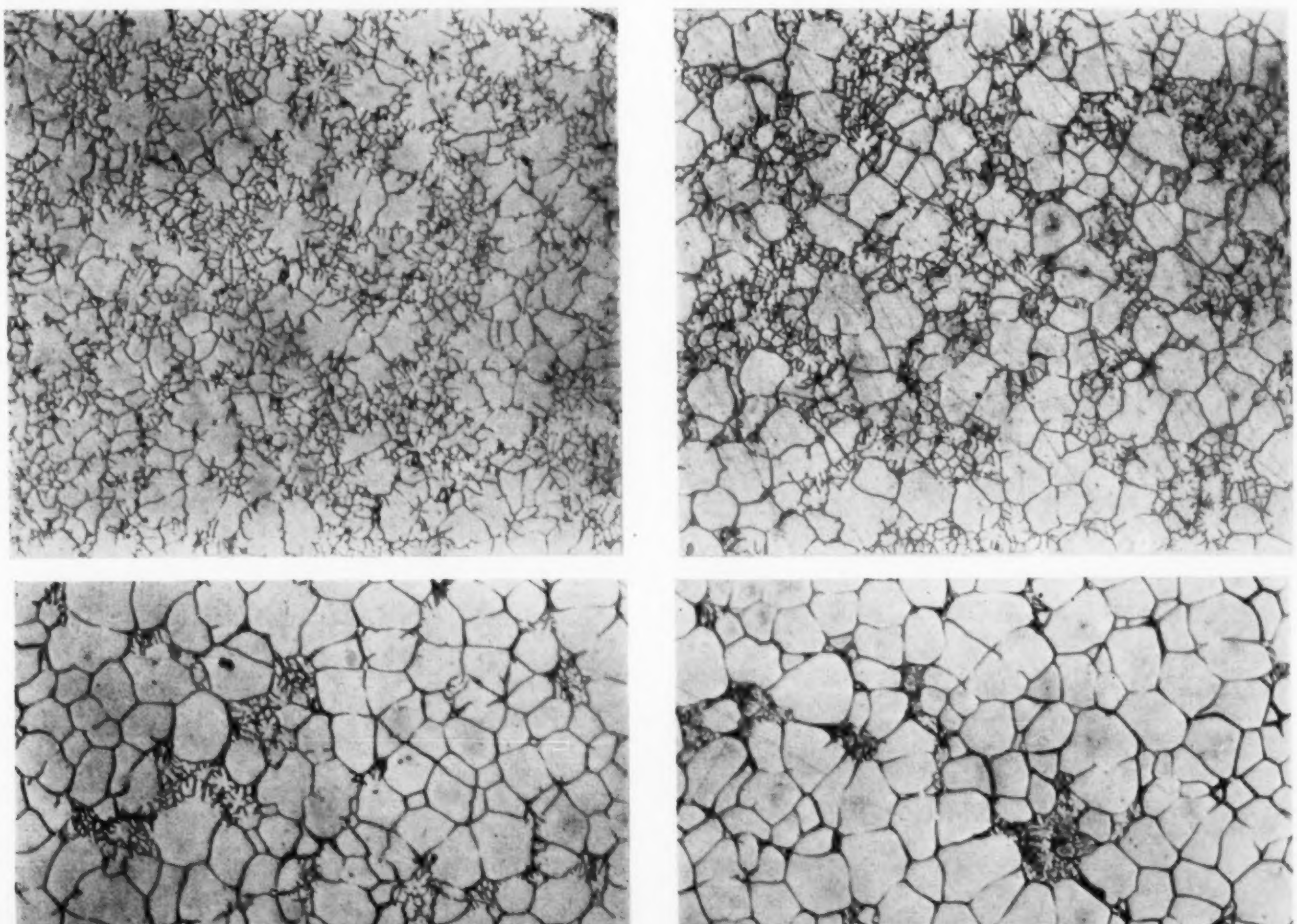

Fig. 4 – Solidification progress of EZ33A. 100×. Upper left – quenched at liquidus. Upper right – quenched at 10F below liquidus. Lower left – quenched at 20F below liquidus. Lower right – quenched at 30F below liquidus. (Continued on next page.)

quite common. The minimum grain size in any given case will depend on composition and grain refinement technique.

Figure 8 shows the effect of cooling rate on the grain size of EZ33A. It is quite apparent that there is little variation in average grain diameters over the entire range of cooling rates. This was not unexpected since the zirconium addition to this alloy is an effective grain refiner. The grain size is established at only 30F (17 C) below the liquidus.

The data show some indication that at low cooling rates the curves should be drawn as a band rather than as a single line. This is better illustrated if grain size is considered on a volume basis rather than as average grain diameters. For instance, when the average grain diameter is halved, the number of grains per unit volume is increased eight times.

Thus, small differences in average grain diameters result in large differences in the number of grains per unit volume. If the data are plotted on semi-log paper as cooling rate vs number of grains per unit volume, the spread in grain size at lower cooling rates becomes more apparent.

The mechanism by which rapid cooling results in fine grain size is perhaps best explained by considering the phenomenon of constitutional supercooling.[8] Solidification of an alloy results in a layer of solute rich liquid at the solid-liquid interface as shown in Fig. 9A. That this solute rich layer actually exists has been shown by Tiller and Rutter.[9] At slow cooling rates the interface temperature is not much below that of the bulk liquid. The thermal gradients through the enriched layer are rather low.

As the cooling rate increases the interface temperature decreases, and steeper thermal gradients are formed which result in a greater degree of supercooling of the enriched layer. Figure 9B shows the liquid temperatures (straight line) and the equilibrium liquidus temperatures (curved line) which result from different cooling rates. The area between the lines represents the degree of undercooling in the liquid.

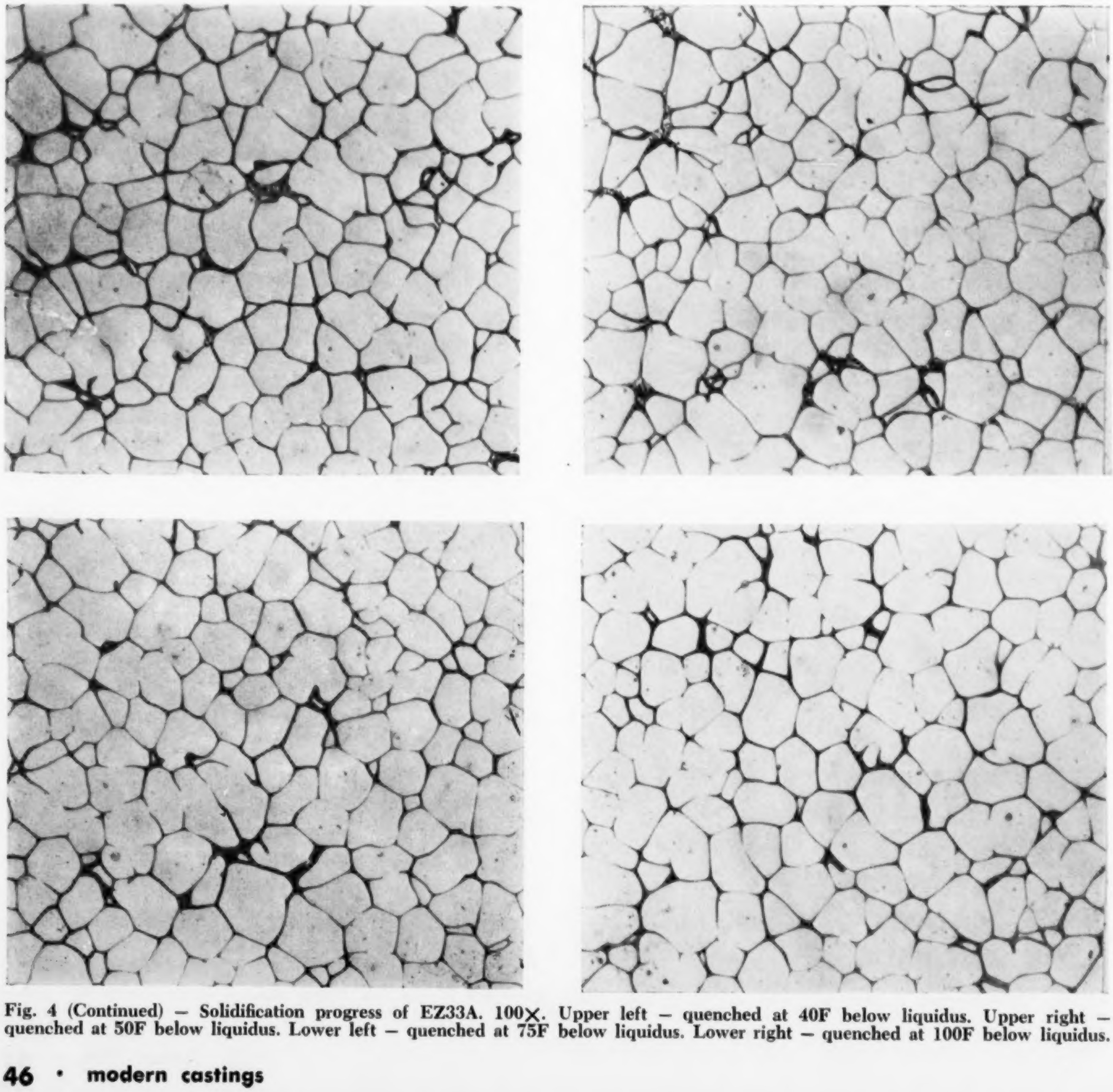

Fig. 4 (Continued) – Solidification progress of EZ33A. 100×. Upper left – quenched at 40F below liquidus. Upper right – quenched at 50F below liquidus. Lower left – quenched at 75F below liquidus. Lower right – quenched at 100F below liquidus.

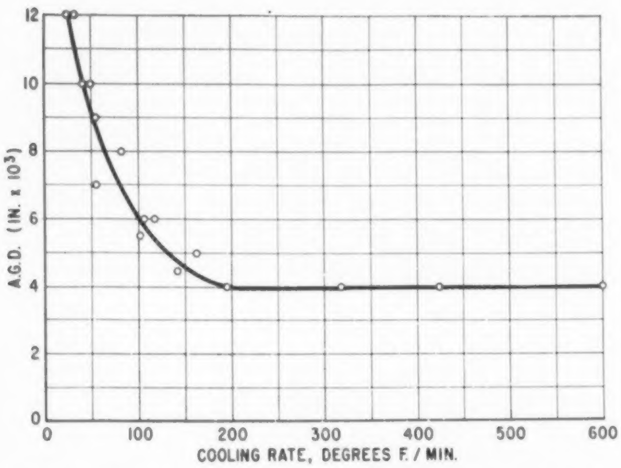

Fig. 5 – Effect of cooling rate on the grain size of AZ63A.

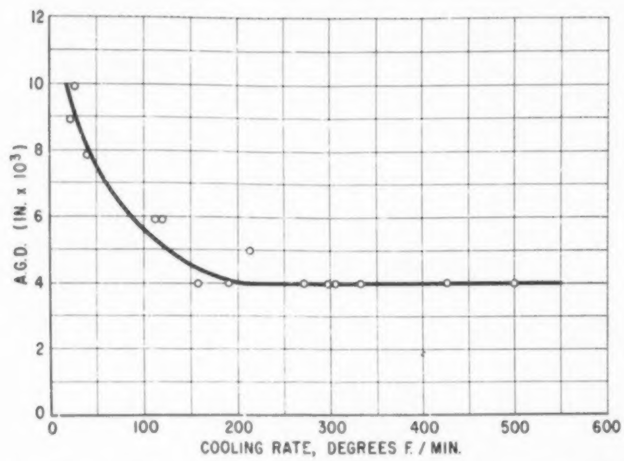

Fig. 6 – Effect of cooling rate on the grain size of AZ92A.

It is well known that as the degree of undercooling increases there is an increase in the concentration of effective nuclei. A greater concentration of effective nuclei results in more grains, i. e., a finer grain size. As shown in Fig. 9B, rapid cooling results in a greater degree of undercooling. This in turn causes an increase in the number of effective nuclei and a finer grain size.

The preceding explanation is applicable to the results obtained with the magnesium-aluminum-zinc alloys. Although the same mechanism is operative in the magnesium-rare earth-zinc alloy, the variation in grain size is not as great since the presence of zirconium apparently produces nuclei which require little undercooling to become effective. Thus, variation in cooling rate has little effect on the grain size of zirconium containing alloys.

The minimum grain size achieved in the magnesium-aluminum-zinc alloy is worthy of consideration. The simplest explanation is that in heterogeneous nucleation it is possible for the preferred nucleation sites to be exhausted.[10] Thus, if there is a finite number of nucleation sites, it should be possible to obtain a degree of undercooling (function of cooling rate) which will cause them all to be effective. Once this condition has been achieved, further increases in the degree of undercooling would not cause any increase in the number of grains formed.

The alternative case is that there was an infinity of possible nucleation sites. Since a minimum grain size was reached, it is obvious that there was some limitation as to the number of nuclei which could become effective. It is safe to assume that in a given alloy system there is a maximum degree of supercooling possible. Since the alloys under consideration had established a grain size at 50F (28 C) below the liquidus, it would seem the maximum degree of undercooling is a function of both cooling rate and temperature. A combination of the two is reached where further undercooling is not possible and the remaining nucleation sites cannot become effective.

CONCLUSIONS

On the basis of the preceding, several conclusions can be drawn about the effect of solidification conditions on the grain size of magnesium casting alloys.

1. The grain size of magnesium alloys is established at temperatures not much below the liquidus temperature. When considering the effect of cooling rate on grain size, the cooling rate through this range should be used rather than the cooling rate through the entire solidification range.

2. The grain size of magnesium alloys decreases as the cooling rate increases to certain values. Further increases in cooling rate result in no additional decrease in grain size.

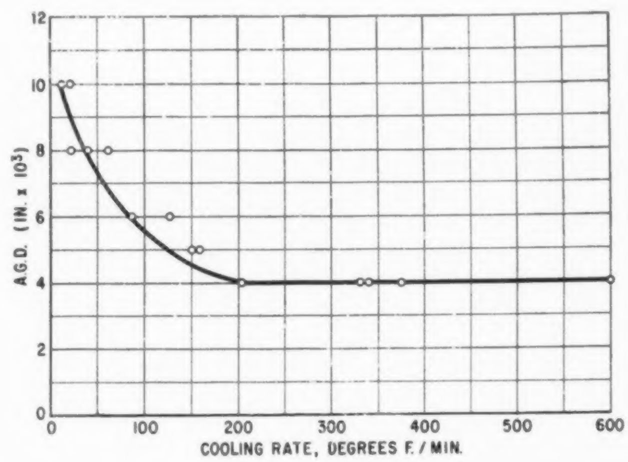

Fig. 7 – Effect of cooling rate on the grain size of AZ81A.

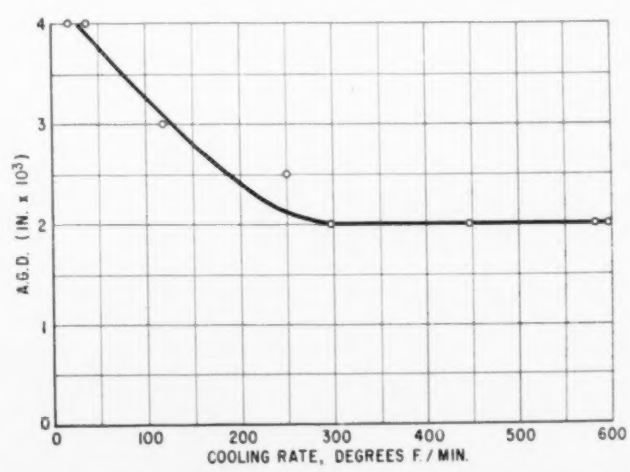

Fig. 8 – Effect of cooling rate on the grain size of EZ33A.

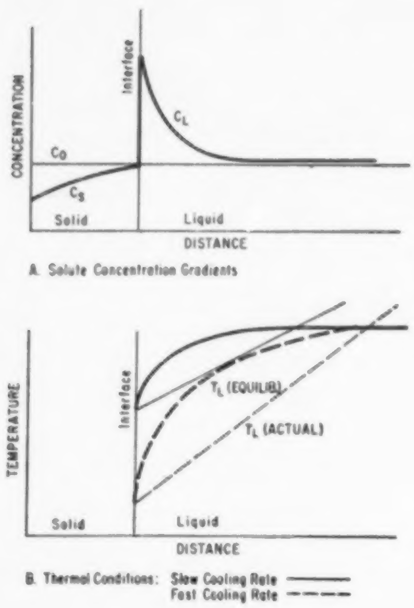

Fig. 9 — Constitutional supercooling. Alloy solidification results in a layer of solute rich liquid at the solid-liquid interface.

3. The nuclei in zirconium containing magnesium alloys become effective with less undercooling than do those in magnesium-aluminum-zinc alloys.

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ANNEALING OF MALLEABLE IRON: EFFECT OF REPEATED ANNEALING ON RATE OF SECOND STAGE GRAPHITIZATION

By

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INTRODUCTION

As a result of studies made in the last 10 years or so of the annealing of black heart malleable iron, our understanding of the kinetics of the process is fairly good. This is especially true in the so-called first stage of the process. Here primary carbide is decomposed at relatively high temperature, usually in the range 1650-1750 F (900-950 C). Schneidewind[1] has ably summarized the data on the quantitative effects on annealing rate of as-cast section thickness, temperature of anneal, and many composition factors.

Our data and understanding are less satisfactory for the second stage of the process where pearlitic carbide is decomposed or its creation avoided to achieve a final ferritic matrix. The metallurgy here is complicated by the fact that there are two quite distinct ways of eliminating pearlite. One way is by avoiding its formation during cooling from first stage annealing temperature through the critical temperature range. The other way is by allowing pearlite to form and then decomposing its carbide by holding at a temperature just below the bottom of the critical temperature range.

Various combinations of the two methods are of course possible. The latter, where pearlite forms and is then decomposed, evidently is similar in nature and kinetics to that for first stage annealing. The relationship in first stage annealing between time necessary for decomposition and temperature of holding has been contributed to and summarized by Rehder[2]. Second stage annealing by this process is therefore for practical purposes predictable, though not as fully as for first stage annealing.

However, most commercial annealing of black heart malleable iron includes a slow cool through the critical temperature range. Here most or all of pearlite elimination is achieved, and sub-critical holding is seldom necessary. This has been not only an historical development, all mealleable annealing being finished in this way until some 30 years ago, but it is still the simplest and most practical second-stage process to apply especially in large furnaces.

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The metallurgy of the slow-cool process of eliminating pearlite has not been adequately explored and is not well understood. However, a start has been made by a description of the apparent equilibrium critical temperature range that exists in commercial irons, as affected by silicon content[3].

A relationship published by Rehder[4] showed that for a given iron, a slow or controlled cool through the critical temperature range gave a ferritic matrix in considerably less time than did rapid cooling and subsequent holding below the critical temperature range. It seems evident that the minimum total annealing time always can be achieved by the slow cool rather than by the holding process. Data by Gilbert[5] and unpublished work by the writer shows that the impact strength of the final iron is better from the slow cool than from the sub-critical hold process.

The facts of less total furnace time, more practical control possibilities, and higher toughness of the product, make the slow-cool second-stage anneal the more valuable commercial process. Our knowledge of this second stage should be extended.

OBJECT OF PRESENT WORK

It is occasionally necessary to re-anneal malleable or other iron due to retention of either primary carbide or of pearlite. Little is known of the effect on annealing or carbide stability of re-cycling through the temperature involved. It is well-known that the decomposition of carbide by heat is additive. If 10 hr holding at 1750 F (954 C) is necessary to decompose all of the primary carbide in a given iron, two separate five hr periods at that temperature will accomplish the same result.

The same is true of pearlitic carbide. If either primary cementite or pearlite remain in an improperly annealed iron, they can be eliminated by reheating to the appropriate temperature for a suitable time.

However, if it is primary carbide that must be eliminated, the heating to above the critical temperature range re-forms austenite and the second stage of anneal must be repeated. If only elimination of small quantities of pearlite is required a re-heat and hold at just below the critical temperature range will be sufficient. This is true only if a furnace is available with the required good temperature control.

TABLE 1 – WHITE IRON COMPOSITION

C, %	Si, %	Mn, %	S, %	P, %	Cr, %
2.52	1.50	0.41	0.155	0.044	0.040

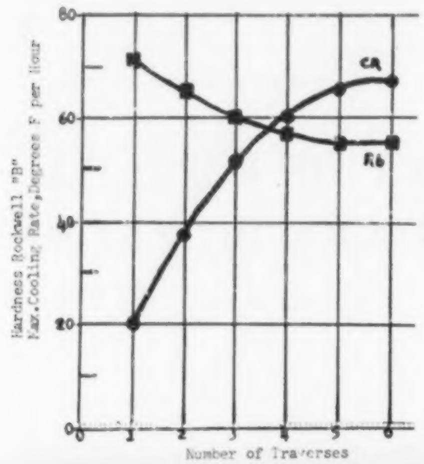

Fig. 1 – Relationship between number of anneals, hardness, and annealing rate.

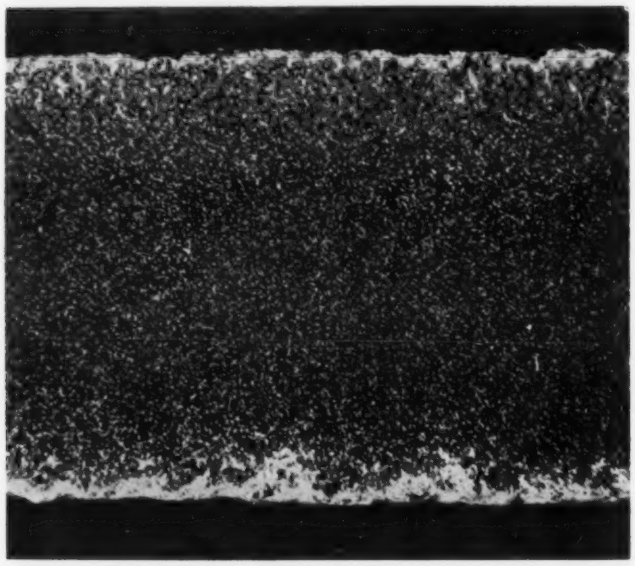

Fig. 2 – A pearlitic rim formed at the as-cast surfaces during the first traverse. Etched. ×6.

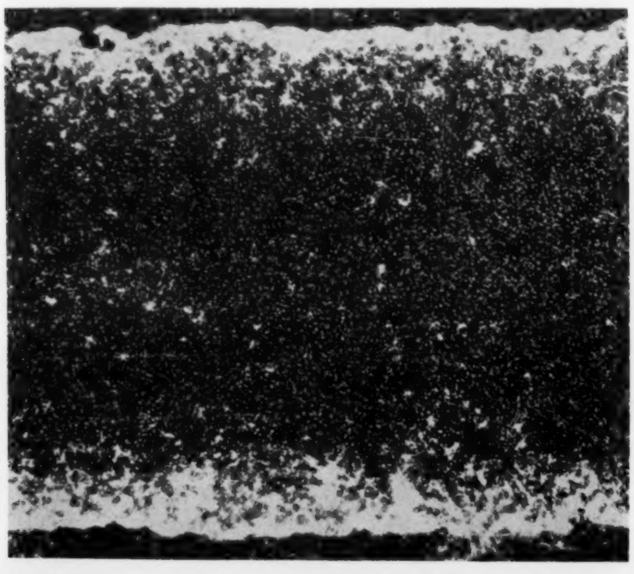

Fig. 3 – The pearlitic rim formed during the first traverse at the as-cast surfaces deepened during succeeding traverses. Shown is the sixth traverse. Etched. ×7.

Usually retention of pearlite is handled by a nearly full re-anneal since it is more convenient and does not require extra equipment. In either case the effect of re-anneal on second-stage stability is important, and to the writer's knowledge has not been published. It is the object of the present short study to determine this effect.

The fact that the data to be developed are applicable quantitatively to nodular irons, gray irons and white irons, will bear repetition since in the writer's experience all data on the kinetics of graphitization so apply.

METHOD

In outline, the procedure was to re-anneal a commercial white iron several times and to then determine the annealability or maximum annealing rate of the product. The white iron was in the form of bend test bars, 5/16-in. thick, 1-1/4-in. wide and 8 in. long. The test bars were poured from regular production cupola-air furnace duplexed iron of a Canadian iron company. The bars were cast in pairs in green sand from a single ladle. Drillings gave the composition shown in Table 1.

The time necessary for first stage graphitization was determined by quenching samples of the white iron from 1750 F (954 C) at intervals and examining the structure for presence or absence of primary carbide. The time necessary for this material was found to be 2-1/2 hr ± 1/4 hr. The maximum permissible cooling rate for second-stage anneal was then found by taking small pieces of the white iron and individually heating them to 1750 F (954 C), holding 2-3/4 hr, and cooling from 1450 F (788 C)–1300 F (704 C) at various rates. The resulting microstructure was examined for pearlite. The maximum cooling rate at which complete freedom from pearlite could be achieved was found to be 20 F ± 2 F per hr.

Six lengths of the white iron were then packed in cast iron chips in a shallow stainless steel tray. This was put into a muffle furnace at 1200 F (649 C) and heated at full power input to 1750 F and held at temperature for 2-3/4 hr. It was then cooled at maximum furnace cooling rate with power off to 1450 F, equalized at 1450 F for 15 min, and then cooled from 1450 F-1300 F at a controlled rate of 20 F per hr. A check of the resulting microstructure showed it to be completely ferritic.

One of the bars was then cut into small samples, and these were individually reheated to 1750 F and soaked for 15 min to re-dissolve graphite to form a homogeneous austenite. It was then cooled at maximum furnace rate to 1450 F, equalized for 15 min, and cooled from 1450 F-1300 F at various rates to determine the maximum cooling rate at which the resulting structure was completely ferritic. This was found to be 37.5 F ± 2.5 F per hr.

The five bars remaining from the first-stage anneal and first slow cool were then treated in cast iron chips in the stainless steel tray by the re-heat process previously described and cooled from 1450 F-1300 F at 35 F per hr. This provided raw material for the third experimental traverse. This procedure was continued until six complete traverses of the critical temperature range were investigated.

The effect of holding time at 1750 F was investigated, since conceivably further homogenization might result and material that had been through five traverses had been held 60 min longer at 1750 F than the first material. Extra holding at 1750 F was found to be without effect. The maximum cooling rate permissable after holding at 1750 F for 4-1/4 hr was 20 F per hr, as after minimum holding.

With respect to re-solution of graphite prior to a re-traverse of the critical temperature range, it was known that one min at 1750 F after heating in the furnace used resulted in a visually homogeneous microstructure and maximum quenched hardness, so 15 min holding should have been ample.

Hardness determinations were made on the samples resulting from each cycle, using the Rockwell "B" scale and averaging six readings for each determination.

Photomicrographs were taken of structural details, the photomicrographs of Figs. 2 and 3 being taken in oblique light which shows pearlitic rim and temper carbon nodules as white and the ferrite dark.

RESULTS

The maximum cooling rates at which a completely ferritic matrix is obtained, for each of the traverses of the critical temperature range, is shown in Table 2 and Fig. 1. Hardness values of each end product are also given as measured and as converted to Brinell for 500 kg. load.

Although protection from oxidation was nearly perfect, a pearlitic rim formed at the as-cast surfaces during the first traverse and deepened during subsequent anneals. This is shown in Figs. 2 and 3.

A pearlitic rim such as seen in Figs. 2 and 3 did not form at cut or machined surfaces, as shown in Fig. 4.

As-cast surfaces contained a layer free of temper carbon nodules and a thin outer layer which was apparently too low in carbon to form pearlite. This thin outer layer of ferrite disappeared during the 6th traverse, probably from carbon diffusing out from the pearlite layer farther in. This is shown in Figs. 5 and 6.

The temper carbon nodules were considerably larger and fewer near as-cast edges, as seen on a comparison of Figs. 5 or 6 with Fig. 4. This is shown more clearly in Fig. 7.

Annealing Rate

It is evident from Table 2 and Fig. 1 that repeated traversing of the critical temperature range increases the second-stage annealability of malleable iron by a considerable amount. The largest percentage increase is on the second traverse or the first re-anneal. The reason for or the mechanism of the change is obscure, as is that of the graphitization reaction.

The first thought that it might be connected with greater opportunity for diffusion and homogenization, is countered by the fact that longer holding at supercritical temperature, which should produce more homogenization, had no effect on annealing rate. An appreciable decrease in hardness occurred along with the increase in annealability, but even if they were connected the basic mechanism is not known.

Surface Effects

Although protection of the sample from oxidation during annealing was good, as evidenced by the fact that a metallographically polished surface put through an annealing cycle still showed grain boundaries and the texture of temper carbon in nodules, some progressive surface effects took place. Apparently a pearlitic rim can form and deepen on an as-cast surface, but much less readily on a machined surface. This has been noted before by Cowan[5] and the present observations do not increase our understanding.

TABLE 2 – NUMBER OF TRAVERSES VS. MAXIMUM COOLING RATE

No. of Traverse	Max. Cooling Rate, F per hr for Ferritic Matrix	Hardness of Iron Rb	Hardness of Iron BHN
1	20.0	71	112
2	37.5	65	102
3	52.5	60	95
4	60.0	57	91
5	65.0	55	89
6	67.0	55	89

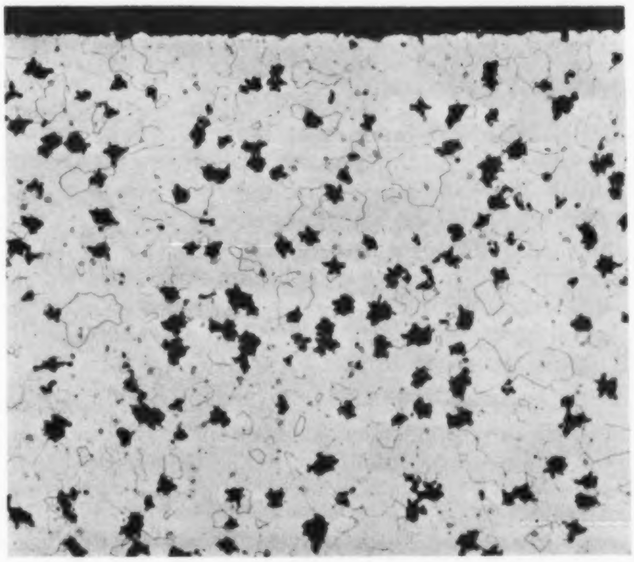

Fig. 4 – The pearlitic rim shown in Figs. 2 and 3 did not form at cut or machined surfaces. Shown is the second traverse, machined edge. 2 per cent nital etch. ×100.

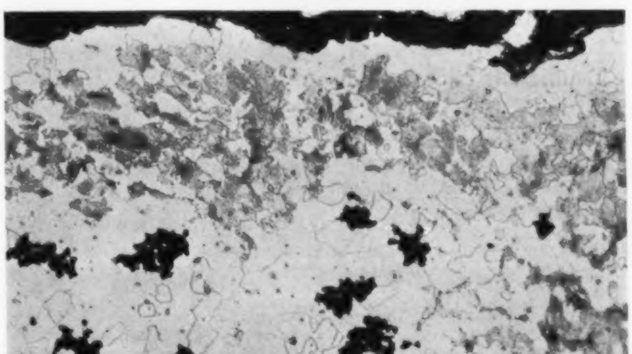

Fig. 5 – The as-cast surfaces contained a layer of temper carbon nodules and a thin outer layer too low in carbon to form pearlite. The as-cast edge, first traverse, is shown. 2 per cent nital etch. ×100.

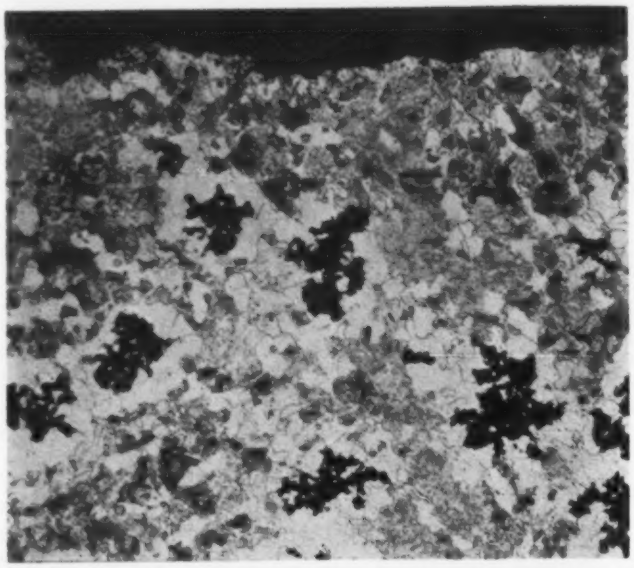

Fig. 6 – The thin outer layer of ferrite disappeared during the sixth traverse. Shown is the as-cast edge, sixth traverse. 2 per cent nital etch. ×100.

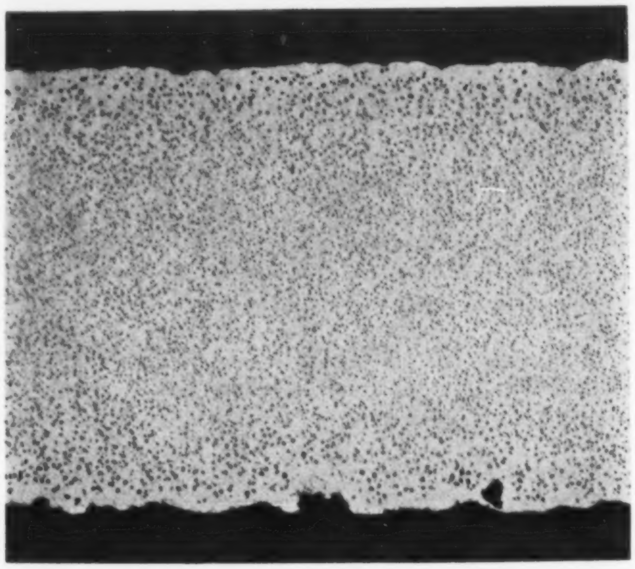

Fig. 7 – The temper carbon nodules are considerably larger and fewer near as-cast edges. Shown is the complete width, first traverse. Unetched. ×6.

It should be noted that the increasing depth of pearlite rim in the present work can be explained on the basis of some given theory of rim formation. It can also be explained on the basis of the as-cast surface of the iron being unchanged in annealability by repeated traverses and the rim deepening with increased cooling rate.

Hardness

The values obtained decrease logarithmically with re-annealing, but since the fifth and sixth results are the same some minimum value seems to be approached. The final hardness is unusually low with no evidence of cause.

Practical Considerations

Practical use of the effect of re-annealing on second-stage graphitization rate can be made in three ways. If re-anneal has been necessary because of retention of primary carbide due to furnace trouble or insufficient time at temperature, the cooling rate through the critical temperature range can be increased for the re-anneal by about 85 per cent with a proportionate saving in time. This is possible of course only when good control over the furnace cycle is possible. Good control of the furnace cycle is the case on nearly all modern furnaces, especially where no packing is used.

If re-anneal is necessary because of retention of pearlite after the regular anneal, then there is some assurance that a repeat at the same cooling rate will eliminate the pearlite since the iron has been rendered more annealable by its first anneal. This effect has been taken advantage of for many years in everyday malleable foundry operation, but there has been no evidence of the size of the advantage possible. It is apparent that an occasional contamination of chromium for example, can to an appreciable extent be taken care of by one or two re-anneals. A second re-anneal at the original rate represents a 160 per cent increase in annealing effectiveness.

Where separation of first stage (decomposition of primary carbide) and second stage annealing is possible, it might appear advantageous to let the furnace charge cool to below the critical temperature range and then re-heat for the slow cool to eliminate pearlite. A faster cooling rate might then possibly be used, but the power and time necessary to re-heat would probably be too high a price to pay. This is because the increase in rate would be minor due to the effect of the pearlite retained the first time. In special cases, such as in the annealing of Delavaud pipe which is relatively high in carbon and silicon and so in annealability, an air cool to below the critical before reheating may be of advantage.

CONCLUSIONS

The above data are considered to show that:

1. The process of eliminating pearlite in iron of black heart malleable composition by slow cooling through the critical temperature range, is affected strongly by the thermal history of the material.
2. The effect is towards greater annealability, and amounts to as much as 85 per cent on the first repeat.
3. The effect is apparently independent of soaking time at high temperature.
4. The hardness of the material decreases as annealing is repeated.
5. The mechanism or cause of the effect is not known.

ACKNOWLEDGEMENT

The cooperation of the Physical Metallurgy Division of the Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada, was available for the studies described here and was much appreciated.

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EFFECTS OF FOUNDRY VARIABLES UPON POROSITY OF 85-5-5-5 BRONZE

By
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ABSTRACT

This report describes the effect of four important variables: pouring temperature, moisture content of green sand, chilling, and depth of machining, upon the pressure tightness of 85-5-5-5 castings. Following procedure described in previous reports[1,2] 2-in. × 2-in. × 12-in. long bars were cast under controlled conditions in molds of different sand compositions and with varying chill design. Critical specimens were sampled at various depths beneath the surface for determination of leak rate.

Pouring temperature variation from 1900F-2300F resulted in progressive change from low leakage to severe leakage for the entire length of the bar.

As moisture content was changed over the range from dry sand to 5.5 per cent maximum, leakage increased only slightly.

Chilling decreased leak rate and shifted location of the porous zone markedly. A variety of tapered chills was employed with success.

Increased leak rate was encountered with greater depth beneath the surface in most cases. Maximum porosity was encountered at the center of the section.

INTRODUCTION

The long-range purpose of this investigation is to determine the important factors governing porosity in 85-5-5-5 bronze. Basically it is recognized that, aside from mechanical gas entrapment, porosity can result from precipitation of dissolved gases or volume changes associated with solidification. However, the relative contributions of these effects are unknown. To complicate the problem, a given void can result from the combined effects of gas and solidification shrinkage.

To provide information leading to the ultimate separation and evaluation of these variables a standard test specimen was developed. The effects of changes in metal history and mold composition upon pressure tightness were observed. Information of immediate value to the foundryman and clues leading to the important variables could be obtained in this way.

In previous reports [5, 6] melting, molding, and pressure testing were reviewed in detail. They will be outlined here for the readers convenience.

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MELTING AND POURING PRACTICE

Melting is done in a gas-fired crucible furnace using 100 per cent ingot under the prescribed oxidizing atmosphere. Just before tapping, 1 per cent zinc is added and then two ounces of phosphorus-copper per 100 lb of metal is plunged in the ladle.

Standard specimens were checked for analysis and found to be within the 85-5-5-5 specification. The standard tapping temperature was 2230 F, pouring at 2025 ± 5 F, except when varied for the pouring temperature series. In the case of the pouring temperature series, the melt was superheated to 2430 F and separate ladles were tapped, deoxidized, and poured at the indicated temperatures. Thus, all bars had the same melt history. Temperatures were measured and recorded with a chromel-alumel couple contained in a thin-walled protection tube.

Pouring technique involved filling the pouring basin fitted with a graphite plug to avoid dross. Molds were poured at an uphill slope of 1 in. per ft to provide a smooth metal flow.

MOLDING PRACTICE

Molds were prepared on a jolt-squeeze machine using metal patterns, synthetic sand, or core sand. Graphite wedges were used as chills. A typical casting, riser, and runner system is given in Fig. 1.

PRESSURE TESTING

A longitudinal slice 2 in.x12 in.x1/32-in. was taken in a horizontal plane at the centerline of the casting

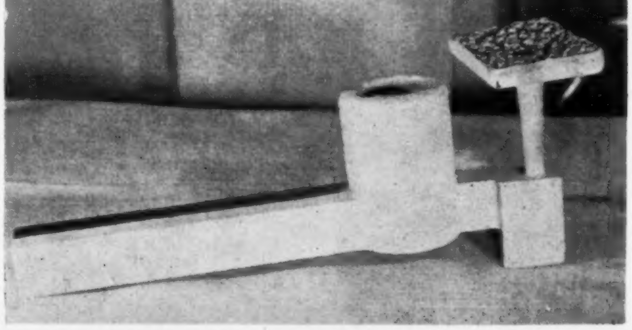


Fig. 1 – Photograph of test casting after sand blasting and identifying marks have been applied.

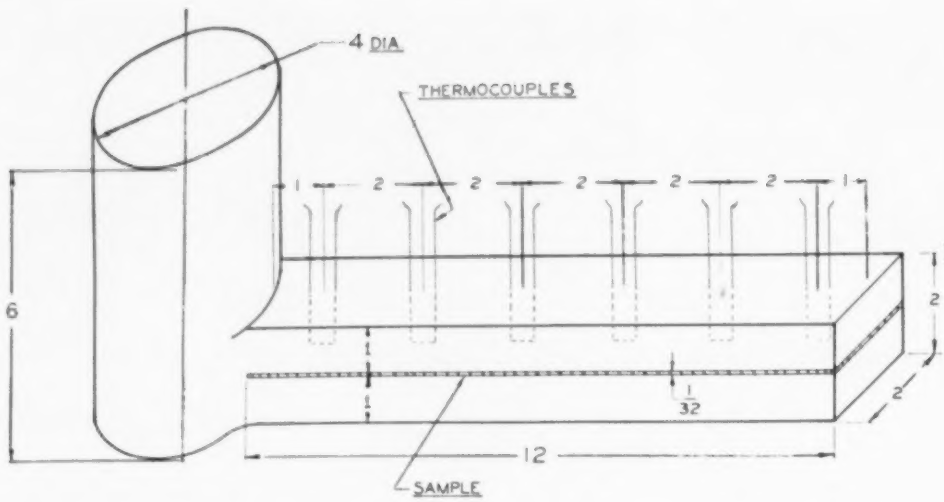


Fig. 2 – Drawing of test casting.

(Fig. 2). Additional specimens were sometimes cut parallel to this at depths closer to cope or drag surfaces. The specimens were finish machined with a shaper using a constant machining practice avoiding smearing.

Testing was performed with compressed nitrogen at 100 psi, measuring the rate of flow through selected 1/2-in. diameter x 1/32-in. thick volumes of the specimen. A plot of leakage rate vs. position in the bar is then made for each specimen (see graphs).

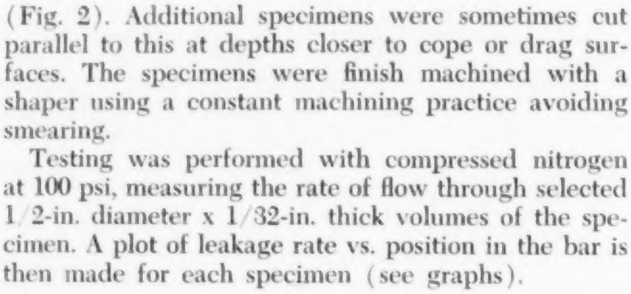


Fig. 3 – Temperature data of geometrical distribution of leakage.

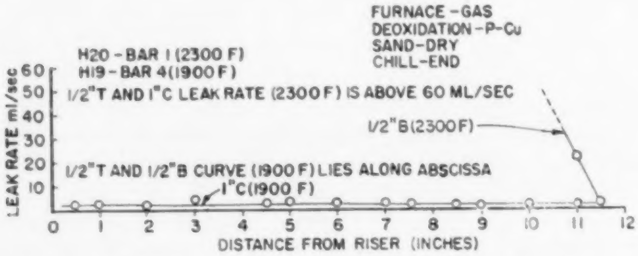


Fig. 4 – Temperature data of dry sand.

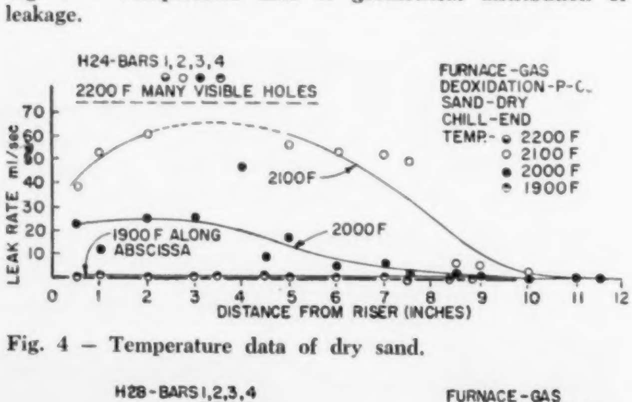


Fig. 5 – Temperature data of green sand.

VISUAL AND METALLOGRAPHIC EXAMINATIONS

The slices were examined in the as-machined condition, and in certain cases after polishing and etching with 30 per cent nitric acid. Selected specimens were cut for micro-examination. In general, macrospecimens with a leak rate below 60 ml/sec do not show any visible porosity.

EXPERIMENTAL DATA

Four variables were selected for principal attention in conference with the research committee:

1) Pouring temperature.
2) Mold material—green sand of different moisture contents, dry sand.
3) The effect of chills.
4) The effect of sample depth in the bar (effect of depth of machining).

Pouring Temperature

Pouring temperature has long been suspected as an important factor in pressure tightness control. The evidence of Figs. 3, 4, and 5 indicates an extreme effect. It is obvious that pouring at low temperatures, (about 1900 F) is very beneficial. Two additional heats were poured with the same type of indications but are not included in the data because of overly long melting time.

It should be emphasized that off-scale leak rates are obtained not only with very high pouring temperatures, but also that variations from 1900 F to 2000 F result in a change of leak rate from 11 to 50 times at critical regions of the bar (the 2-in. station, for example). This factor may also be encountered in critical sections of commercial castings poured over a relatively small temperature range.

This sensitivity to pouring temperature is present both with green-and dry-sand molds. In both cases, the curves follow about the same trend indicating that the region around 1900 F gives best results.

A word of caution in applying these results to actual casting conditions: there is a difference between the pouring temperature and the temperature at which the casting cavity is filled. This depends upon the gating system. Based on some preliminary thermocouple data, it is believed that the temperature drop in this test casting is quite small because of the rapid

pouring rate and relatively large gates. Therefore, a pouring temperature of 2000–2100 F might give the same solidification pattern in a commercial casting with small or long gates or at a slower pouring rate as obtained with 1900–2000 F in the test casting. The emphasis in this investigation has been to determine which foundry variables are important before applying the results.

The metallographic examination of the samples disclosed the following information. All specimens which showed leak rates above 60 ml/sec, poured at 2100 F or higher, showed severe spherical porosity in the upper 1/4–1/2-in. layers (Fig. 6b). It is interesting to note the greatest porosity is just beyond the end-chill affected zone. The gas rejected during the freezing of the first metal concentrated in this zone.

The grain size varied directly with the pouring temperature (Fig. 6a). The low pouring temperature produces an essentially sound, fine-grained microstructure (grains less than 1/16-in. diameter). Only a few fine voids were apparent at 500 diameter. The microstructure of the bars poured at 2300 F exhibited a porous microstructure with large grain size (over 1/4-in.). Columnar structure was not present in any of the speciments to any extent. All exhibited equiaxed grains except in the chilled regions.

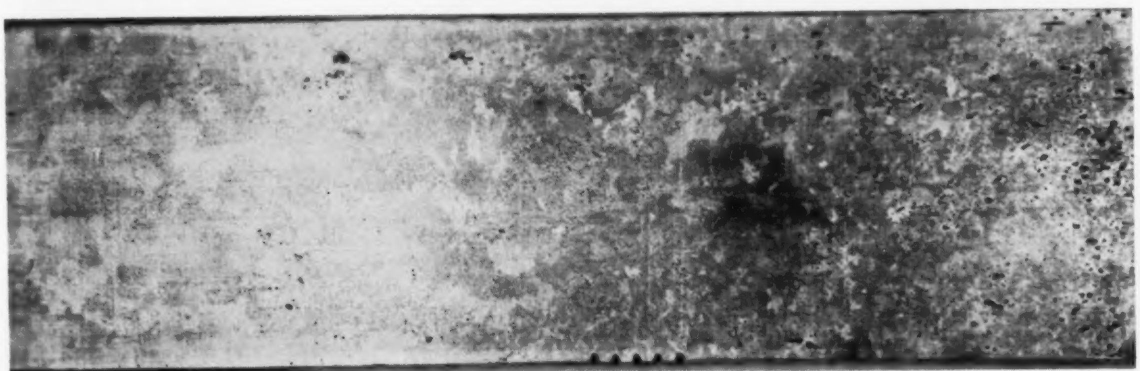
Moisture Content of Sand

The data of Figs. 7, 8, and 9, indicate that in the range investigated (from dry sand to 5.5 per cent H_2O) increased moisture leads to somewhat greater porosity. This variable is not as potent as pouring temperature. It should be pointed out that the values of 2.6 and 5.5 per cent moisture have undesirable working conditions for this sand. They were only employed to give a wide range of water contents for the experiment.

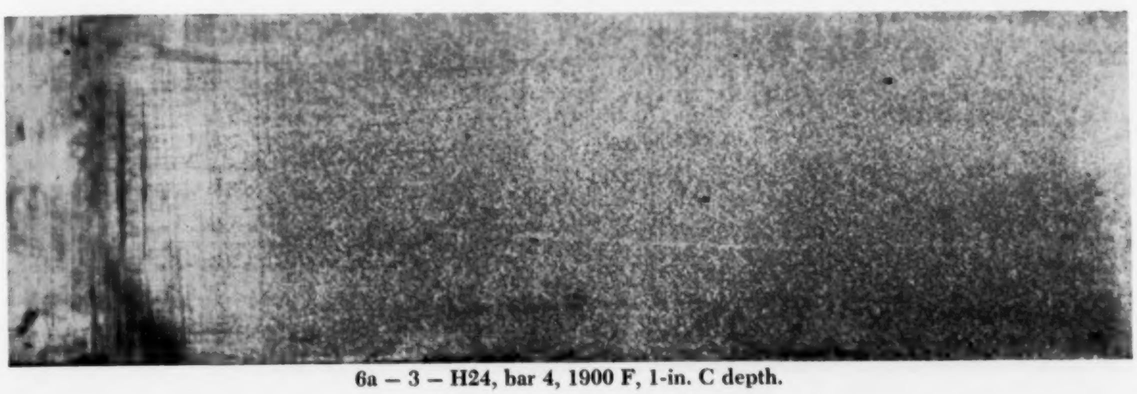
In the attempt to obtain a really dry sand (the so-called dry sand was baked using conventional practice 400 F, 14 hr), a good many molds were calcined

Fig. 6a – Macro-examination of varying temperatures 30% HNO_3 etched. 1X. (Reduced slightly in reproduction)

6a – 1 – H20, bar 1, 2300 F, 1-in. C depth.



6a – 2 – H24, bar 1, 2200 F, 1-in. C depth.



6a – 3 – H24, bar 4, 1900 F, 1-in. C depth.

at 1300 F. Unfortunately, as the tightly bonded water is driven from the bentonite, the mold loses strength and is difficult to assemble. Other experiments are in process in the attempt to provide an end point for the moisture series.

These experiments with moisture content were conducted at a pouring temperature of 2025 F. It is possible that the combination effect of pouring temperature and water content may lead to more severe porosity under other conditions. It is important to separate the possible effect of any gases in the metal resulting from water in the mold by the experiments under way using calcined molds. Fisher[3], for example, has established that under turbulent conditions spherical porosity is more pronounced in oil-bonded sand molds than in green or cement bonded molds.

The Effect of Chills

Two types of graphite chills (Fig. 10, a and b) have been used in addition to the end chill which is standard in all specimens.

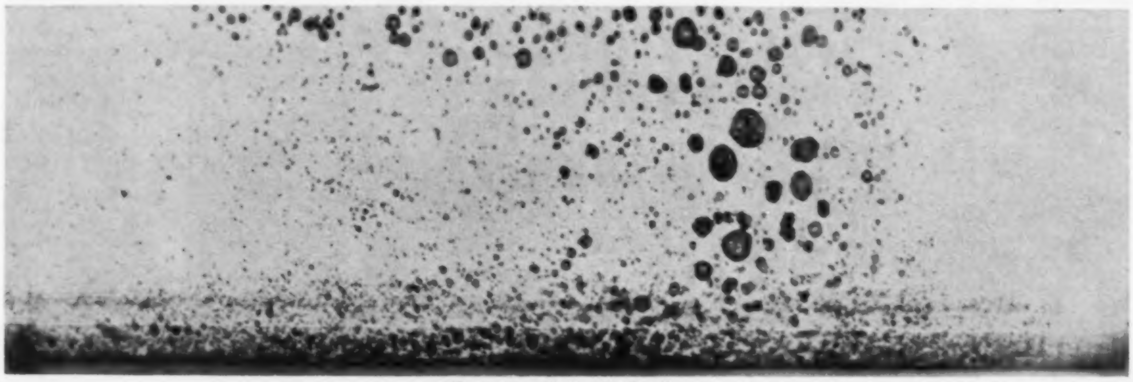
The complete-chill designation indicates that the face or faces labelled as chilled are completely formed by the chill. The chilling varies progressively since the chill tapers from 2-in. thick at the chill end to 0-in. at the riser.

The partial chill employs the same chiller, but these are set on a side in the sand. In the case of the partial chill, the thickness is 2 in. along the whole length of the bar, but the chill contact surface of the bar tapers from 2-in. wide at the end to 0-in. wide at the riser end. In addition the partial chill is cut in half to provide an air space to reduce longitudinal conduction of heat in the chill.

Complete Chill Effects

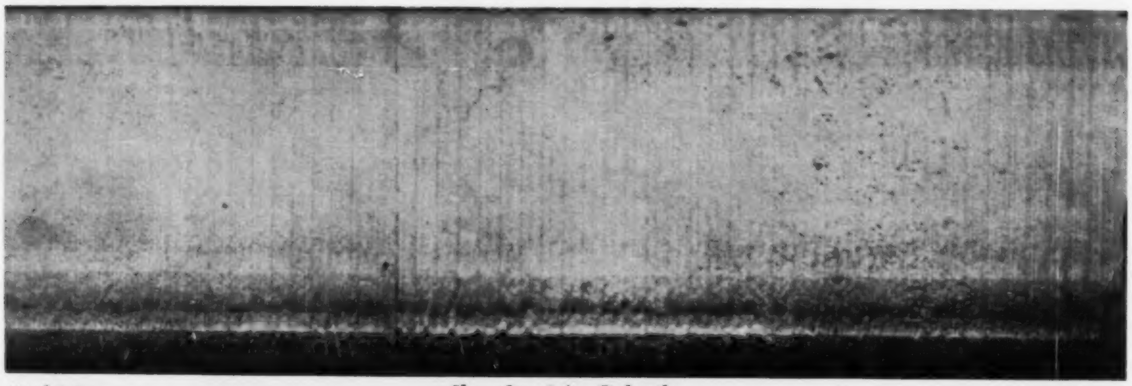
Referring to the complete chill data (Figs. 11, 12, 13, 14), when wedge chills are used on top and bottom only, the leak rate is low.

Fig. 6b – Geometrical examination (as rough machined), H 24, bar 2, 2100 F. 1×. (Reduced slightly in reproduction)



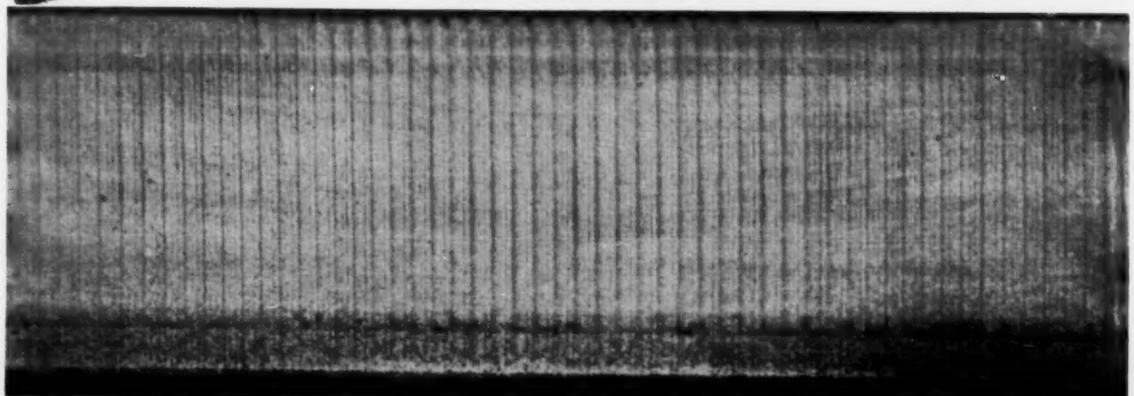
End Chill

6b – 1 – ¼-in. T depth.



End Chill

6b – 2 – 1-in. C depth.



End Chill

6b – 3 – ¼-in. B depth.

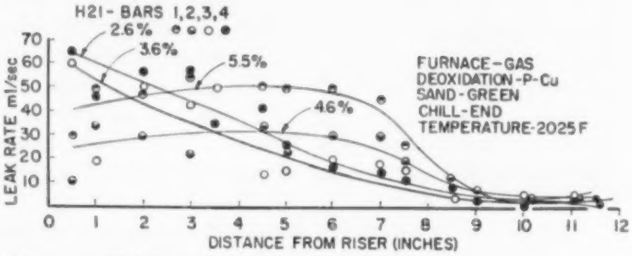


Fig. 7 – Moisture data of green sand.

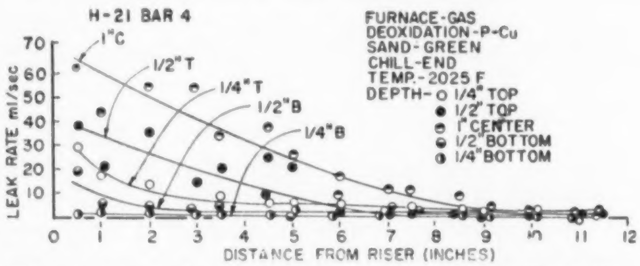


Fig. 8 – Low moisture (2.6%) data of geometrical distribution of leakage.

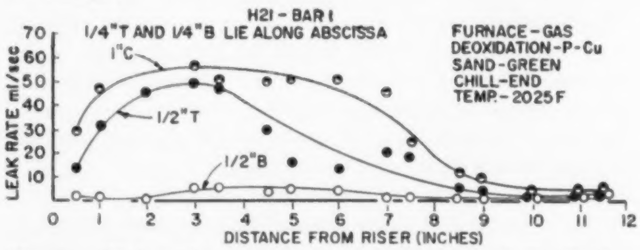


Fig. 9 – High moisture (5.5%) data of geometrical distribution of leakage.

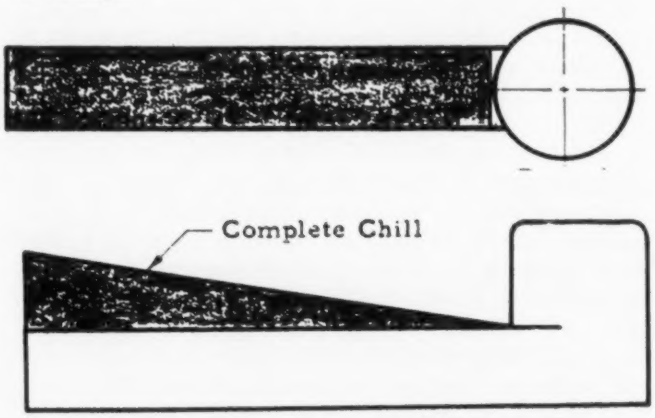


Fig. 10a – Drawing of complete wedge chill. Top – plan view. Bottom – elevation view. Riser end on right.

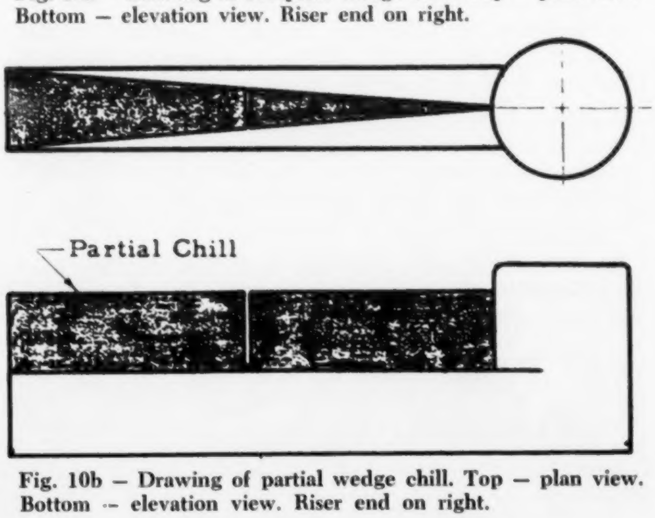


Fig. 10b – Drawing of partial wedge chill. Top – plan view. Bottom – elevation view. Riser end on right.

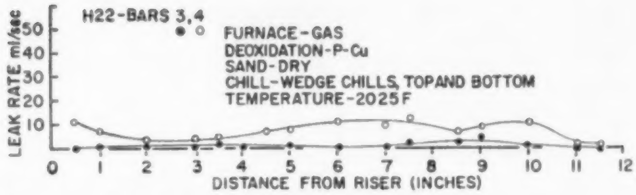


Fig. 11 – Complete wedge chill data (chills on top and bottom).

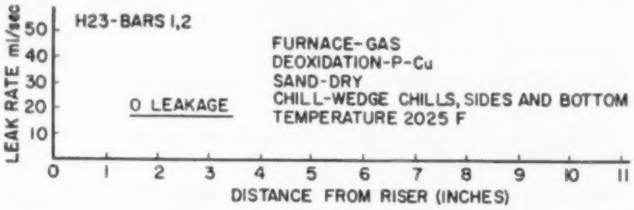


Fig. 12 – Complete wedge chill data (chills on sides and bottom).

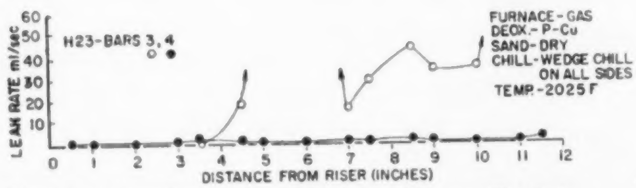


Fig. 13 – Complete wedge chill data (chills on all sides).

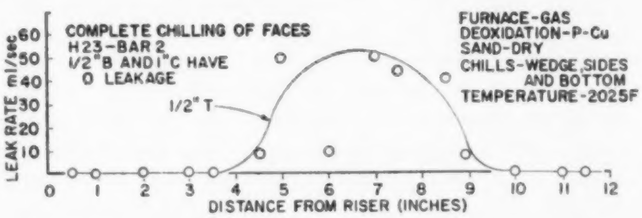


Fig. 14 – Geometrical, complete wedge chill data (chills on sides and bottom).

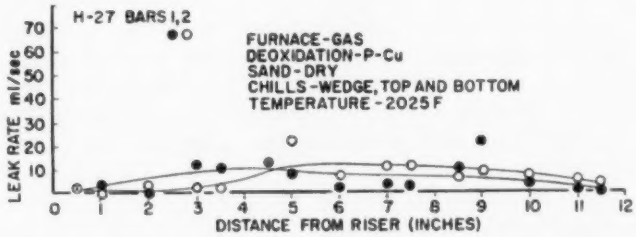


Fig. 15 – Partial wedge chill data (chills on top and bottom).

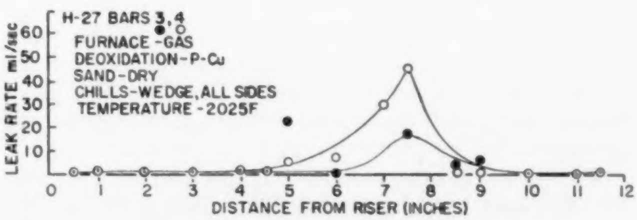


Fig. 16 – Partial wedge chill data (chills on all sides).

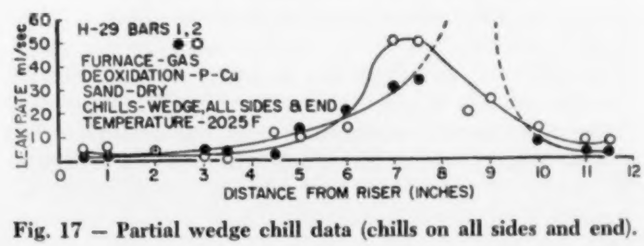


Fig. 17 – Partial wedge chill data (chills on all sides and end).

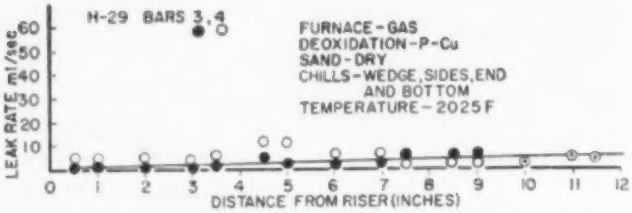


Fig. 18 – Partial wedge chill data (chills on sides, end and bottom).

When chills are employed at the sides and bottom, Fig. 12, the leakage at the standard specimen location is zero.

Figure 14, H23, Bar 2, indicates the porosity has been displaced upward toward the top of the bar. Leakage is noted for a 5-in. long region, 1/2-in. from the top surface.

When the bar is completely chilled on all sides either very good or very poor conditions are obtained (Fig. 13, H23, Bars 3 and 4). The poor results are probably caused by entrapped air, since the mold (completely chilled) is impermeable.

Partial Chills

Partial chills on top and bottom produced effects comparable to the complete chills. In the case of partial chills on all four sides and the end, a short unsound region was encountered starting at the center and proceeding toward the chilled end of the bar. When only the bottom and two sides were chilled, good soundness was obtained as in the case of the partial chills. The unsound region has probably been displaced upward as in the previous case of the complete chills.

It is evident that a given region may be made sound by chilling. The porosity is displaced rather than completely eliminated under the temperature gradients of this experiment and at 2025 F pouring temperature. The data indicate that there is some shorter bar length which can be made completely sound by proper chilling. Quantitave data as to the gradient required for soundness may be clearly obtained by properly instrumented work of this type.

Interrelation of pouring temperature and chilling effects offers much promise.

Effect of Sample Depth

In many castings, centerline porosity can be tolerated if sound metal is present to an appreciable depth beneath the surface. Conversely, there is little merit in obtaining a sound core if the outer regions are spongy.

For these reasons, a study of the effect of specimen location has been surveyed. The data indicate that in almost all cases, the centerline of the bar is the most critical location. The porosity of the upper layers is usually more severe than in the lower layers (Figs. 3, 8, 9, and 14).

In the two bars from the moisture series, (Figs. 8, 9) the leakage at positions away from the centerline follows the same distribution as at the centerline but is less in magnitude. The designations in these figures of 1/4-in. T, 1/2-in. T refer to depth of sample from the top surface, whereas 1/4-in. B, 1/2-in. B refer to distance from the bottom surface. The center sample is 1 in. from both faces. In the mold with the higher moisture, the 1/2-in. T leakage behavior curve is further from the 1/2-in. B curve than in the lower moisture content bar. This is probably related to different amounts of mold reaction.

The effects of location in the temperature series bars (H19, H20), Fig. 3, are also of interest. The bar poured at the lower temperature shows no leakage at either 1/2-in. T or 1/2-in. B locations, while the bar poured at 2300 F exhibits severe leakage at all locations.

CONCLUSIONS AND RECOMMENDATIONS

Pouring temperature, chills, and depth of testing are variables which affect pressure tightness readings severely. Moisture content of the mold is less significant in the range tested.

From the results of this work, it is evident that for pressure tightness castings should be poured at low temperatures. If necessary, gating should be adjusted to permit this condition. Chilling is particularly effective in removing porosity from critical regions. In heats made according to good commercial crucible furnace practice, maximum porosity is encountered at the thermal center of the casting.

The data of this and previous investigations strongly suggest that it is necessary to perform critical experiments to isolate the effects of gas and solidification shrinkage. Gas may be dissolved in the metal during melting and superheating, from the ladle or from the mold. It is important to evaluate these individual contributions and compare them with the role of liquid to solid shrinkage.

ACKNOWLEDGMENT

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THE EFFECT OF SIZE OF SCRAP ON THE TAPPING TEMPERATURE OF A CUPOLA

By

N. H. Keyser* and W. L. Kann, Jr.**

Most foundrymen know that the size and quality of the scrap in the charge will affect the operation of a cupola. Although most operators of cupola know the general nature of these effects, few know them in sufficient detail to apply numbers to the effects. This paper describes the results of an investigation to determine quantitatively the effects of changes in the size and weight of pieces of cast iron scrap on the tapping temperature and required coke ratio in one particular type of cupola operation.

The operation under study was unusual in two ways. First, the charge contained an unusually large percentage of cast scrap. Because of its large amount, the behavior of the cast scrap had a big influence on the behavior of the cupola. Second, the operation of the cupola is unusually critical because of stringent requirements for close control and excellent uniformity of the iron produced. These requirements are mandatory for the manufacture of high-quality abrasive shot.

The cupola is lined to 54 in. in diameter and has a stack height of 22 ft from bottom plate to charging door. It is charged with a mechanical cone-bottom system, and is tapped continuously. The melting zone is jacketed for cooling with water. Several in. of acid fire brick line the inside of the cupola against the water jackets. Normal acid operation is used.

With a metal charge of 2,000 lb, a coke charge of 255 lb, and a blast rate of 4,000 cfm, the melting rate is about 11 tons per hr. The tapping temperature is about 2780 F. The weights of the charge materials (including air) are carefully measured and controlled according to good practice. During this investigation, the cupola produced iron with a nominal composition of 3.30 per cent carbon and 1.70 per cent silicon. Other target compositions are used at other times.

In the series of experiments described here, the 2000-lb metal charge contained 1,700 or 1,800 lb cast scrap. This portion of the metal charge was carefully sorted so that all of the cast scrap in a particular charge fell into one of the three following classifications:

1. Light scrap—Relatively lightweight cast scrap with section thicknesses of about 1 in. or less.
2. Heavy scrap — Drop-broken machinery cast scrap with individual pieces heavier than in light scrap, and with section thicknesses from about 1–4 in.
3. Mixed scrap—Approximately equal weights of light scrap and heavy scrap.

None of the cast scrap in any of the charges was either unusually light or thin, nor unusually heavy or thick. All the scrap was within limits normally considered satisfactory for a cupola of this size. The intention was to determine the effects of variations in the weight and thickness of the scrap when the variations were still within ordinary commercial limits for good practice. The effects of extra light scrap or extra heavy scrap were outside the scope of the study because both of these materials are already known to have undesirable effects.

The balance of the metal charge (200 or 300 lb) was made up from steel scrap and pig iron in proportions calculated to compensate for differences in chemical composition between the light cast scrap and the heavy cast scrap. Slightly more steel was used with the light scrap than with the heavy scrap.

The three types of metal charges were used over an extended period to determine their effects on the operation of the cupola. Recognizing the advantages of a fixed blast rate, the blast rate was held constant. Compensations for the effects of different types of metal charges were made entirely by adjustment of the amount of coke in the charge. This report deals with the amount of coke necessary to correct for the changing in tapping temperature which accompanied the use of each of the three types of metal charges.

The results showed that if the coke charge and the blast rate were maintained at a fixed level, a change in the type of metal charge had a large effect upon tapping temperature. Under these conditions, a change from light scrap to heavy scrap lowered tapping temperatures by about 150 F. When the blast rate was held constant, the tapping temperature could be maintained constant if the change from light scrap to

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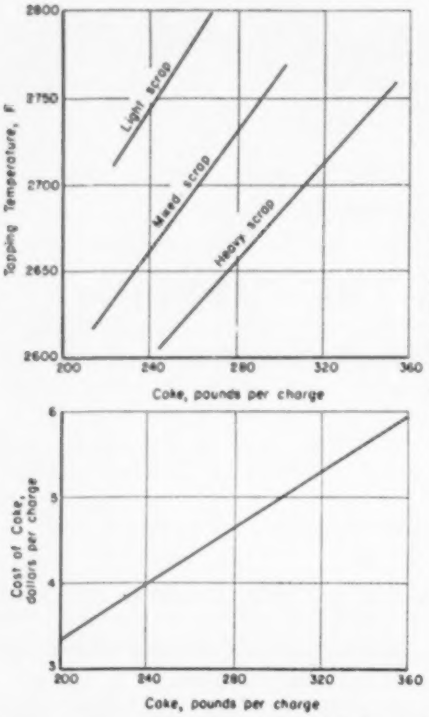

Fig. 1 – Effect of size and weight of cast scrap on tapping temperature and cost of coke for a particular 54-in. cupola operated with a blast rate of 4,000 cfm.

heavy scrap was accompanied by a large increase in the weight of the coke charge. Table 1 illustrates the amount of coke needed to produce a given tapping temperature with each of the three metal charges.

Table 1 is given for a constant blast rate of 4,000 cfm. The effect of changes in blast rate was of secondary interest in this study, because, in general, the advantages of a fixed blast rate in this operation offset the potential advantages of using a variable blast rate. It is pertinent to mention that an increase of 10 to 20 lb in the weight of the coke charge produced an increase in tapping temperature about equal to the increased temperature obtained by raising the blast rate from 3,500 cfm to 4,500 cfm.

Figure 1 summarizes the data obtained during the study. Reduced tapping temperatures were obtained

TABLE 1 – COKE NEEDED TO PRODUCE TAPPING TEMPERATURE

Tapping Temperature, F	lb of Coke Required for each 2000-lb Charge		
	Light Scrap	Mixed Scrap	Heavy Scrap
2700	220	260	305
2750	240	290	340

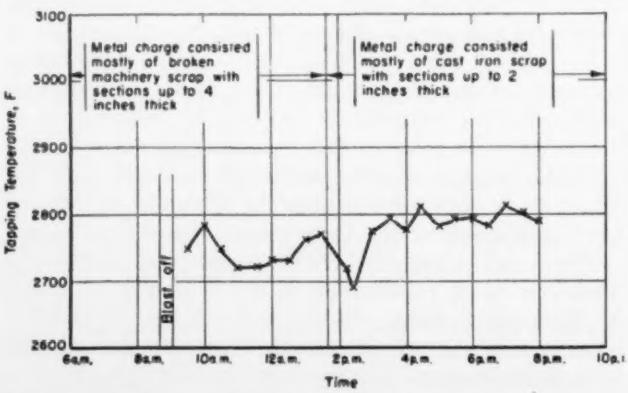

Fig. 2 – Partial log showing effect of size of scrap on the tapping temperature of a particular 54-in. cupola operated at constant blast rate and constant coke rate.

at a given coke rate when the size and thickness of the scrap was increased. Additional coke was needed to compensate for this effect. The added cost of coke is also given in Fig. 1.

The effects shown in Fig. 1 were determined under commercial conditions. They have been verified by continued operation of commercial cupolas. Figure 2 depicts a partial log of one day of operation. It shows how the tapping temperature was increased by an intentional change to lighter scrap part way through the day, and without a corresponding change in either coke rate or blast rate.

A few words are in order about the mechanism by which heavy scrap lowers the tapping temperature, and by which an increase in the coke charge increases the tapping temperature. Assume that a cupola is melting 1-in. cast iron scrap and has an operating bed height of 40 in. This means that all the scrap has been heated to about 2100 F and is melted by the time is descends to a level 40 in. above the tuyeres. The molten iron drops through and dribbles over 40 in. of incandescent coke so that the iron is superheated to say, 2700 F.

When the thickness of the scrap is increased to 4 in. the larger pieces do not melt so fast. If the coke rate and blast rate are maintained constant, coke will burn out at the same rate as when the lighter scrap is charged. This means that the slower-melting thicker pieces of scrap will penetrate lower in the cupola before they are completely melted. If they penetrate to 30 in. above the tuyeres, the operating bed height has been reduced to 30 in. The molten iron will dribble through only 30 in. of incandescent coke (instead of through 40 in. as with the thinner scrap), and will be superheated to a lower temperature, say, 2650 F.

If more coke is added to the cupola charge at the same time that the size of scrap is increased, the additional coke will reach the top of the bed about the same time as the heavy scrap. The added coke will tend to raise the bed, and the heavy scrap will tend to lower the bed. If the amount of coke is properly selected, the two effects will balance out.

The principles and the directions of the effects will be the same for other types of operation and for other cupolas. Only the magnitudes of the effects will be different. Close control of any cupola requires specific information on the magnitude of these effects.

In the foregoing discussion, the required change in coke rate was made in the same charge that the type of scrap was changed, and the blast rate was maintained constant.

Contrast this procedure with that sometimes used in foundries when the size of the scrap is changed. At first, nothing is done. Then, after the tapping temperature goes up or down (as the case may be), and the composition and chill depth of the iron are affected appropriately, an additional booster of coke is added (or should we take some coke out?). Simultaneously (but before the disrupting influence known as the booster reaches the bed), the blast rate is increased (or should we lower the blast?). Under these conditions, not uncommon in some foundries, the bed height moves up and down and the tapping temperature fluctuates greatly.

CREATING A CLIMATE FOR MANAGEMENT DEVELOPMENT

By

R. B. Parker*

The job of finding and developing top executive material is becoming more important daily, and I think the AFS is to be congratulated for selecting the subject as the theme of this meeting.

Before I start on this, perhaps I should tell you a bit about our company, in the event that some of you may feel that while the theories work for us they may not for other organizations.

We operate plants in 37 cities and 18 states in this country—55 plants in all—plus four more in Canada, one in France and one in Mexico. There is a headquarters division, nine separate operating divisions and three subsidiaries. Compared to many firms, the plants are not large, ranging from less than 100 employees to 500 or 600, but in total we employ approximately 10,000 people, who are members of 67 different unions. Fifty-three of our 61 plants are unionized, and 38 of them are foundries.

We manufacture a very diversified product line, ranging from railroad brake shoes and automotive brake lining to wearing parts for excavating and crushing machinery; from steel forgings and hydraulic pumps and valves to alloy castings and air compressors; from railroad car wheels to truck tire molds.

Because we are primarily a group of small plants, many of them foundries, we have both the management problems of the small plant as well as the communications problems of a multi-plant operation. But no matter what the size of the company, top executive development is a basic requirement for success.

The concern of this paper is the intangible qualities of a good executive—qualities which I maintain are common to all men having the attributes of leadership, whether or not they know anything about the foundry business. A man may not know an invoice from a sand mold, but if he has the kind of qualities I am writing about, the chances are he is potentially good management material.

Given a little time, any intelligent man can acquire an adequate knowledge of the procedures and techniques of business and finance. What he cannot acquire are the intangibles—creativity, imagination, judgment, integrity, an analytical mind. These are the key attributes of leadership, whether it is exercised on the playing field, the battleground, or in business.

To a large degree they are attributes that cannot be learned. The most we can do is to try to discover their presence, and then open the doors of opportunity to those who have them.

Careful selection of the most highly qualified candidates is the indispensable first step in any good management development program. This is not as simple as it sounds. At the author's company, for instance, it was learned that a man must be known thoroughly before you can be sure he is the man he seemed to be when he first caught your attention. You cannot know him merely by an occasional casual conversation about foundry operations, or by periodic check-ups on his work, or by watching how he handles himself in group meetings, or even by calling him in for a conference two or three times a year.

Before you can safely appraise his potentialities you have got to know him as a personality—to know his likes and his dislikes, his preferences and his prejudices, his ambitions and his fears, his strong points and his shortcomings.

In effect, of course, this means that you must know him as an individual, not simply as an employee. It means, perhaps, getting together with him on a non-business basis—exchanging ideas at lunch or over a cup of coffee, give-and-take discussions during dinner or a drink, informal "bull sessions" at company outings or similar get-togethers. There is no better way to locate the essential spark in a man than by rubbing his ideas together.

Once we have found the man, obviously, the next step is to train him, to teach him how to use his assets to best advantage. This calls for effective communications, an area in which too many managements lack direction and know-how. I do not intend to digress into a discussion of communications theories and techniques. I simply want to stress the fact that the teaching process should not be a sporadic one, a hit-or-miss matter of merely exposing executive candidates to company practices and policies from time to time, or of holding a series of management training sessions and then expecting the "graduates" to be ready to manage.

The training process must be a continuous one, year in and year out. At the author's company it is believed it should be an extremely comprehensive

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program, designed to familiarize potential executives with all phases of company operations. In a diverse multi-plant firm such as ours, the process is apt to be more complex than in the average foundry, which as a rule tends to be a relatively small operation. Nevertheless, the principle is the same: give executive candidates a good grounding in all aspects of the business, and do it thoroughly, systematically, and continuously.

We try to do it by a variety of techniques: by a consistent two-way communications policy, all the way up and down the line; by trying to create an atmosphere in which it is all right to challenge an established policy to find out why it was adopted; to fight your boss when you think you are right; by spelling out our aims, and the obstacles in the way of their achievement; and above all by such practices as inviting potential bosses to participate in the discussion of problems which are not directly related to their own job.

Often, for instance, meetings of our division heads are also attended by their subordinates, to give them a better grasp of top management problems and solutions. Our information center program is another effective training and communications medium. This was started primarily because there was inadequate transmission of company policy from the chief executive in New York and headquarters service departments along the line to our foremen and plant managers. It was also started because of unintentional (and maybe some intentional) distortion in policy interpretation.

The program consists of a series of meetings for groups of superintendents, foremen, engineers, salesmen, and accountants. The sessions last three or four days, and are designed to be as informative as possible. Top management officials discuss their functions and relate them to the business as a whole. Questions are encouraged, and are given complete, frank answers, many times by the president himself. You all know what fun it can be to be able to quote the president to your immediate boss.

I can assure you that by the time the four days are over everyone has benefited. Top management representatives learn what makes their subordinates tick, and get a good line on the sort of executives they would make. The subordinates get a behind-the-scenes slant on company policies, and find out what it takes to make them function effectively.

They also become imbued with the feeling that they are really a part of the management team. They begin to think like top management men, studying various department problems from every angle, appraising possible solutions with a much broader company point of view, sparking ideas, and generally functioning as an executive should function.

I think the next important step in the creation of a satisfactory management development climate is to broaden the experience of potential executives, by giving them more executive responsibility. You can train a man till the foundry falls down, but you will never really know whether he can handle responsibility until you give him a chance to handle it. What is more, if you regard him as top management timber you would be wise to give him responsibility in a variety of capacities.

At the author's company we move potential executives from job to job, a practice described as "horizontal promotion." The purpose here is to widen the men's experience and give them an opportunity to see how problems are handled in departments other than their own. From time to time, too, we ask them to sit in on meetings involving such varied activities as: plant labor negotiations, product pricing arguments, pension system planning, discussions with lawyers, plans for the preparation of the annual report, and so forth.

This kind of exposure to top management problems and activities brings a man out of himself and creates an atmosphere in which he can grow. All we ask is that he have the seeds of growth within him.

This brings us to what I consider one of the most important of all steps in effective top management development: letting executives put their ideas into practice. This means giving them freedom: freedom to plan, to venture along untried paths; freedom from interference, even when you doubt the value of their programs; freedom to take risks, and to fight back when their ideas are opposed by their superiors. Most of all, it means what we call "freedom to fail." Unless a man is free to go ahead with his ideas, despite the risk of their failing, you cannot really be sure of his potential as an executive.

We believe it is much more serious a blot on a potential executive's record for him not to have tried another way than to have tried and had his plan fail. A man learns far more from his failures, particularly when they are the result of courage—the courage to try another way.

Naturally, you must know your man before you grant him such freedom. Know him as a person, expose him to various types of executive problems and responsibilities, and then give him his head. If he is of executive caliber this will reveal it as nothing else can.

Do not worry about his making mistakes. He will make some, never fear. But if you have chosen your man carefully his successes will far outnumber his failures. And they will bring benefits which would probably never be realized without this exercise of the freedom to fail.

I think this freedom represents the principal key to sound management development, for this reason: it stimulates men to "reach out," as we say at our company—to extend themselves to a degree impossible to men whose judgment and abilities are throttled by the knowledge that their actions are constantly subject to top management approval and criticism.

One of the great needs of management is for men who are eager to reach out in this way: to reach out for more responsibility, for more knowledge, and for more and better solutions to management problems.

There are few more important jobs for top management today than to find and develop men with this capacity for reaching out. You cannot do it by being satisfied with a man's accomplishments in his own department. Find out if he has ideas and abilities in other directions too. You will be surprised at what you may discover: salesmen who have practical suggestions for improving production operations, production supervisors who know how to improve your

annual report, accountants who have constructive advertising ideas.

Let me cite a couple of examples from my own experience. A sustained slump in the sales of nonmetallic bearings once had one of our plants in danger of a shutdown. A production foreman at the plant, happening to find a file full of old repeat orders for bearings, noticed that the orders were several years old. None of the customers had done business with the plant since their orders were last filled.

The plant's salesmen had not followed up the accounts, nor had anything else been done to keep them active. The foreman took the orders to the sales manager and suggested that salesmen be sent out to try to renew the accounts. His suggestion was followed, and much of the old business came back—at a particularly critical time. As things turned out, the foreman's "reaching out" action was instrumental in putting the plant back on its feet.

Another example concerns an office boy who was promoted to supervisor of our duplicating department, simply because he had the initiative to reach out beyond his regular duties and learn all about the machines in this department. It was not long before he knew more about them than the man who had been running them—a service man from outside the organization.

I imagine some of you have known of similar instances. You have probably also experienced a feeling of frustration on occasion when you knew of a better way to perform some operation in another department, and did not feel that you had the right to point it out.

We had an excellent opportunity, on a large scale, to test the practicality of this reaching out technique after World War II. Then we began to grow rapidly and at the same time found ourselves faced with a serious shortage of trained specialists. In desperation we were forced to fill key jobs with men who lacked the training for them. For example, we moved a comptroller into sales management, promoted a purchasing agent to a division vice-president, shifted an office accountant into labor relations, and converted the company's assistant treasurer into a medical and safety director. Incidentally, this man is president of the company today.

I am glad to be able to say that these experiments worked, beyond our greatest expectations. If they had not, I am not so sure I would have had the chance to be in this spot today.

I think we have learned three important lessons from this experience. First, we found that, as a rule, a man with exceptional ability in one area is likely to have outstanding abilities in other areas too. Second, we learned that it is a mistake to place more emphasis on a man's formal experience than on his qualities as a man. And finally, we discovered that the reaching out process not only stimulates a degree of teamwork not possible under other conditions, but also produces a continual flow of interdepartmental ideas, real work satisfactions, and deep company loyalties.

In short, we learned that it is unwise to create a group of specialists functioning under the domination of a single individual. The days of management dictatorship are gone. Today's top executives must be leaders, not autocrats. You cannot run a company as a one-man operation and expect to develop executive leadership in others.

Too many foundries, it seems to me, tend to be top-down, one-man operations. But management is too complex an operation today for any one man to have all the answers, to spark all the ideas. Successful management embraces so many areas: manufacturing, buying, selling, financial negotiations, governmental activities, and so on. Most important of all, it requires a knowledge and understanding of the human factor. No one man can possess all the skills necessary to operate a company at full effectiveness. To do the job properly you need the ideas, the abilities, and the leadership of many men.

Essentially, the job of top management is to help men discover and develop their talents. The success of a foundry operation, perhaps more so than in the case of many other businesses, depends largely upon the caliber of its management—all of its management. As you know, there is a scarcity of skilled executives in the foundry business today, and, as a result, there is a great deal of competition for the services of men with top management abilities.

This is another reason why it is important to spread management responsibility, just as it is another reason against the one-man-dominated, top-down management operation. You cannot run a one-top executive team, rather than just top executive.

In a speech before the American Management Association a couple of years ago, the manager of International Harvester Company's education and personnel department made this comment: "Today almost the only unique advantage a company can have is the possession of resourceful, aggressive, imaginative management at all levels." He went on to stress the importance of giving men a variety of assignments in order to develop them into top management material. To illustrate his point, he cited a survey of Harvester top executives which showed, among other things, that they "did not think of any regular job with the company as having been much more important than any other in their development; rather, they attached greater significance to certain special assignments . . . invariably outside the usual scope of the positions held."

That is why at our company we believe in giving a man a variety of jobs, rather than just confining him to a block on an organization chart. Let me give you an an example. When one of our foundries needed an advertising manager we did not limit our search to men with an advertising background. For one thing, few of them had any real familiarity with foundry terminology. However, in one of our research departments there were several men who did know the language. We did not let the fact that none of them had any advertising experience prevent us from considering them. Finally, one of these men, a metallurgist, was chosen for the job.

Yes, he made some mistakes in the beginning. But not nearly as many, we think, as might have been made by a regular advertising man dealing with an unfamiliar technical subject. Furthermore, our metal-

lurgist never made the same mistake twice. It was not long before he was handling the job like an expert.

An interesting postscript to this story, by the way, is the fact that this same man was made a sales manager of another division, a job in which he performed with equal success.

A similar example is the case of the foreman who was promoted to editor of our company magazine. Before this the publication had been edited by people who knew how to write, but who lacked an understanding of foundry workers and methods. As a result, the magazine had done little to improve employee relations.

Our foreman-editor knew his people, and knew foundry operations and problems. And, because he too was a "reacher-outer," with abilities beyond those of his foreman's job, he was able to succeed where his predecessors had failed.

Along these same lines, years ago, when we needed a new sales manager, it was customary to give the job to our best salesman. Today we know better, and select a man who knows how to build an effective sales force, whether or not he happens to be a star salesman himself. For that matter, he need not even be a salesman at all.

My point is obvious: do not be afraid to switch men around when there is a job to fill. Do it even where there is not any job open. Remember, in the average foundry there are only a few top jobs. To get the most out of each one, do not pigeon-hole your executives. Do not breed a group of specialists, capable of handling only the problems in their own little province. You cannot build an all-around management team that way.

Do not make the mistake, a very common one, of thinking that because a man is a salesman, or an accountant, or whatever, that that is all he is capable of being. For all you know he may be in his present sphere only because that is the one in which he first got his start in the business. But he may actually have more capabilities in some other direction. You will never know until you give him a chance to prove himself, until you create a management climate that will give him a real opportunity to extend himself, to reach out beyond the borders of his present job.

This, in my opinion, is the secret of developing a top executive team, rather than just a top executive.

SHELL MOLDING FOR STEEL CASTINGS

By

R. G. Powell* and H. F. Taylor**

ABSTRACT

Surface defects generally occuring on low-carbon and low-alloy steel castings in shell molds can be eliminated by the use of chill-type shell molds. Such molds can be made with forsterite or cheap blends of granulated limestone and silica sand. The chilling effect, in the respective cases, depends on the high conductivity of forsterite, and on the endothermic dissociation of limestone plus the endothermic reaction of CO_2 with carbon from the resin binder.

INTRODUCTION

The unacceptable surface condition produced on low-carbon and low-alloy steel castings made in shell molds, is perhaps the greatest deterrent to more widespread use of shell molding by the foundry industry. Even though it is a relatively expensive process, shell molding does offer definite advantages over conventional molding. It is hoped the information presented in this article will help steel founders to adapt the process to many of their castings.

Previous research sponsored at M.I.T. by the Steel Founders' Society of America[1] and by Watertown Arsenal[2] led to the belief that the cause of the surface defects on low-carbon and low-alloy steel castings was an unfavorable time relationship. This time relationship was between skin formation of solidifying castings and the strong evolution of gas by the resin of the shell molds. Improvement in surface condition of castings resulted when 1) manganese dioxide or calcium carbonate powder was added to silica sand-resin mixtures, and 2) when zircon, chrome ore or especially olivine was used instead of silica sand.

The substitute refractories were believed beneficial because of their chilling effect. They promote skin formation of castings. No satisfactory explanation was found for the role of manganese dioxide and calcium carbonate.

A recent research project, sponsored by Watertown Arsenal, gave results which confirm the original theory on the cause of the surface defects. The role of forsterite in curing these defects was clearly established. The beneficial functions of manganese dioxide and calcium carbonate powders were explained. Practical techniques developed are described in this paper which make it possible to adapt shell molding to the manufacture of low-carbon and low-alloy steel castings regardless of section size.

CAUSE OF SURFACE DEFECTS

In the belief that surface defects result because the skin of castings formed simultaneously with development of high gas pressure in the molds, a study of equilibrium data was made. From these data the researchers hoped to determine other elements which, like increased carbon, would delay skin formation of steel castings. Boron, titanium and silicon were selected for testing.

It was found that about 0.030 per cent boron was sufficient to produce a surface on steel castings comparable to the excellent surface obtained with cast iron. Boron develops poor mechanical properties in steel when more than 0.004 per cent is used. As expected the castings were extremely brittle. Tests with titanium indicated that about 1.5 per cent titanium would be required to obviate the usual surface defects. However, the mold-metal reaction occurred because of the great reactivity of titanium.

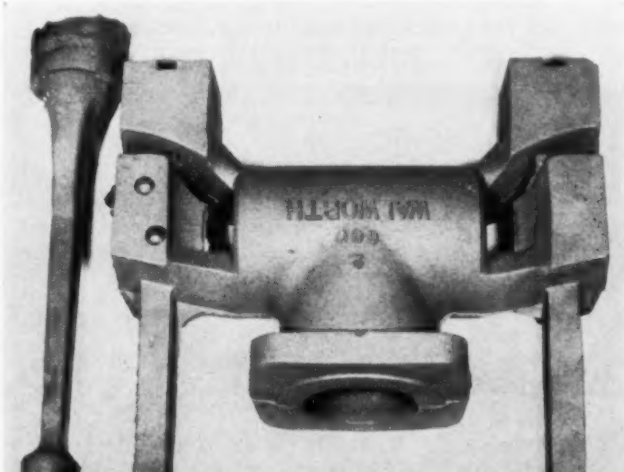

Fig. 1—Industrial casting, weighing about 35 lb, made of low-carbon steel modified with 1.5 per cent extra silicon in a shell mold containing 3.0 per cent Fe_2O_3.

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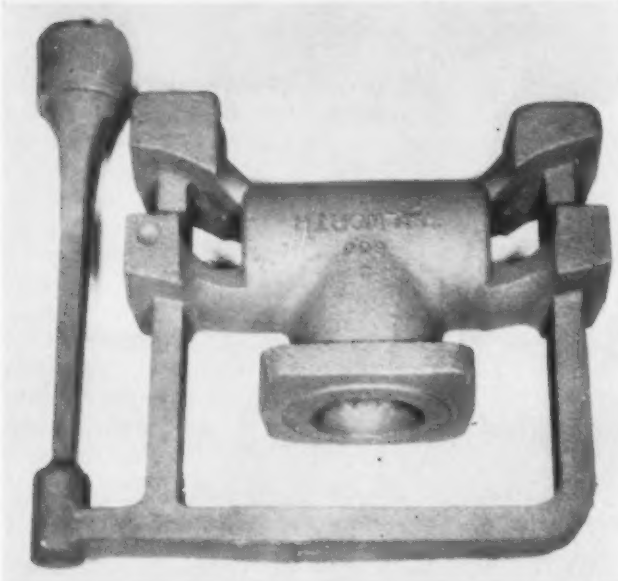

Fig. 2—Same casting as in Fig. 1, made of low-carbon steel in a shell mold containing 3.0 per cent Fe_2O_3.

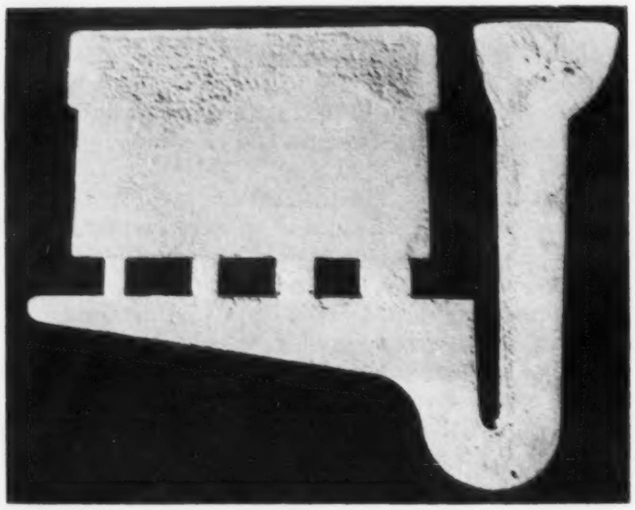

Fig. 3—Back of experimental casting weighs about 13 lb, made with low-carbon steel in a silica sand-resin shell mold.

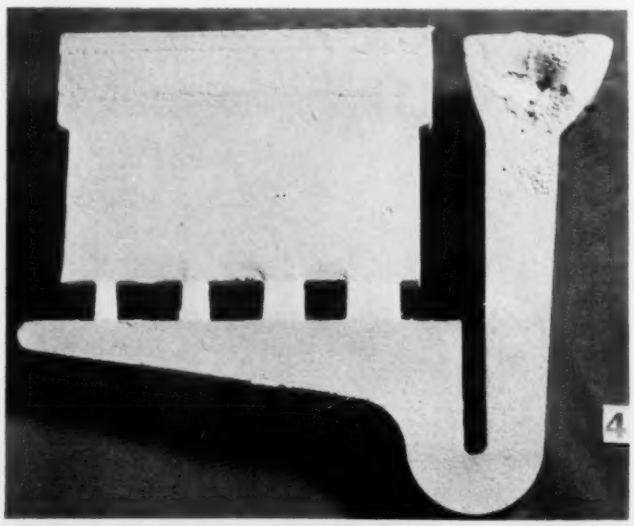

Fig. 4—Experimental casting made of low-carbon steel in a forsterite shell mold, poured at 2900 F.

Silicon, a more acceptable element in cast steel, completely eliminated surface defects when used in amounts of about 2.5 per cent.

Further work with silicon modified steel in molds containing additives showed that equivalent results could be obtained with only 1.50 per cent silicon when the sand-resin mixture contained iron oxide. With 1.25 per cent silicon when manganese dioxide was the additive the results were the same. An industrial casting made with steel containing 1.5 per cent silicon in a mold containing 3 per cent iron oxide is shown in Fig. 1. For comparison, a casting with a normal amount of silicon made in a similar mold is shown in Fig. 2.

It is not practical, particularly from the specifications standpoint, to modify carbon steel compositions as a means for controlling casting surface defects. Nevertheless, the results of these experiments are valuable. They strongly support the time-relationship theory as the basic cause of surface defects, and suggest that oxidizing agents added to the molds are beneficial as they advance the time of gas evolution.

EFFECT OF FORSTERITE

Results obtained with forsterite as mold material are illustrated by the castings shown in Fig. 3 and 4. In regard to the chilling effect of forsterite, a confused situation existed. This is because it gave better results than zircon. Zircon had been rated a better chill than forsterite in a previous study on the chilling ability of various molding refractories.[3] This chill rating was made from data taken on the solidification of relatively large steel spheres with a thermocouple in their center. However, there is a fundamental difference between a surface chill and a section chill, so it was concluded that forsterite probably was a better surface chill than zircon.

This was investigated by making grain-size observations on M-bronze castings. Thick shell molds of

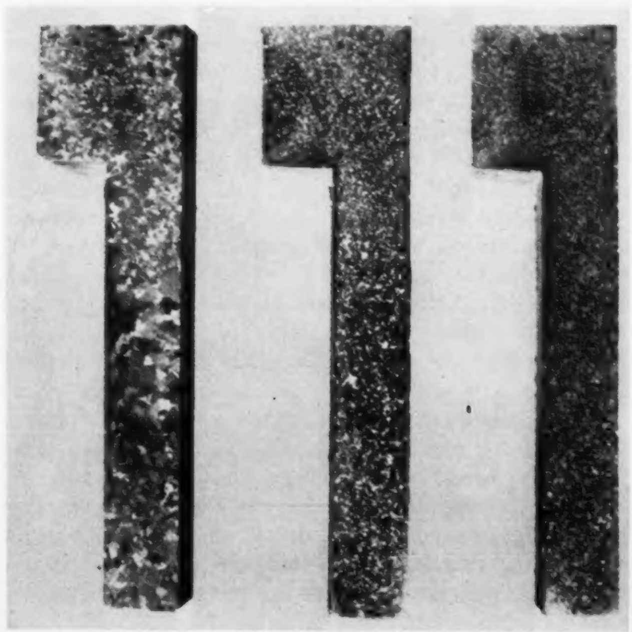

Fig. 5—M-Bronze castings in shell molds illustrating the chilling effect of zircon (center) and forsterite (right) in regard to silica sand (left). Etched with nitric acid. Reduced slightly in reproduction.

silica, zircon, and forsterite were poured at the same time through a common sprue arranged with three runners. The metal was poured at 2100 F. Observation of grain sizes showed that forsterite can be a better surface chill than zircon on steel castings. In fact, with high conductivity bronze, its greater chilling effect was felt throughout the 1 in. thick section of the casting (Fig. 5).

Following these experiments, data on the thermal conductivity of olivine (commercial forsterite) were furnished the authors by Dr. Aslak K. Valheim of the Government Raw Materials Laboratory in Trondheim, Norway. Olivine is extensively used in general foundry practice in Norway. These data (Fig. 6), indicate that olivine has three to four times the conductivity of silica sand at low temperature. Its conductivity, however, decreases rapidly with increasing temperature while that of silica sand increases.

In comparison, the thermal conductivity of zircon is about twice that of silica at low temperature. Its conductivity decreases much less rapidly than that of forsterite with increasing temperature.

It is generally accepted that the fundamental equation of solidification of metal in a mold is:

$$X = M\sqrt{t} \qquad (1)$$

where X = the thickness of metal solidified after time t.
M = the constant of solidification.

Chvorinov has defined this constant in terms of metal and mold properties. He has expressed the above equation as follows:[4]

$$X = 1.158 \frac{T\,b}{Q\,S} \cdot \sqrt{t}\;^{*} \qquad (2)$$

where T = the solidification temperature of the metal.
Q = its heat content of solidification and superheat.
S = its specific gravity.
b = the heat-diffusivity coefficient of the mold.

In turn, b is equal to the square root of the product of the mold conductivity, specific heat and specific gravity:

$$b = \sqrt{K C_P \rho}$$

Equation 2 shows that the amount of metal solidified after a certain time varies directly with the heat-diffusivity coefficient of a mold. Since the mold properties defining b vary somewhat with temperature, average values over a range of temperatures are used to determine X. This is legitimate when treating solidification of casting sections, and when the mold properties do not change appreciably during the time of solidification.

The present problem, however, concerns skin formation of castings. It is the low temperature properties of the molds that must be considered. Approximate values of diffusivity coefficients of silica sand, zircon, and forsterite at low temperature have been calculated and are presented in Table 1. This shows that forsterite initially in a mold has greater cooling ability than zircon, and about twice that of silica sand. The fact that the conductivity of forsterite

*Dimensional units: meters, cal, kg and hr.

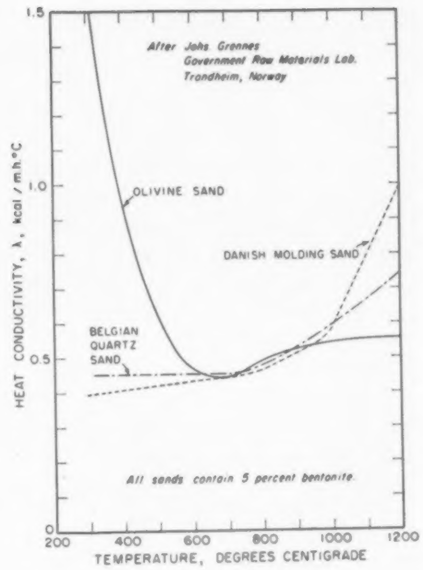

Fig. 6 — Conductivity of olivine compared with that of silica sand.

greatly decreases with increasing temperature explains why the material is not as good as zircon for a section chill on steel castings.

EFFECTS OF MnO_2 AND $CaCO_3$

The tests with silicon modified steel indicate that manganese dioxide in shell molds would advance gas evolution. Previous measurements showed that manganese dioxide delayed gas evolution while calcium carbonate advanced it.[2,5] These measurements were made under steel casting conditions which caused extremely rapid evolution of gas, and their accuracy was questioned. New measurements were made with conditions under better control, using a technique similar to the AFS standard method for gas determination of core binders.

TABLE 1 – HEAT DIFFUSIVITY COEFFICIENTS OF MOLD MATERIALS AT LOW TEMPERATURE

	K*	C_P*	ρ*	b*
Silica sand	3.14×10^{-3}	0.21	2.6	4.15×10^{-2}
Zircon	5.16×10^{-3}	0.16	4.6	6.15×10^{-2}
Forsterite	9.42×10^{-3}**	0.24	3.2	8.50×10^{-2}

* in CGS Units
** taken as 3 times K of silica

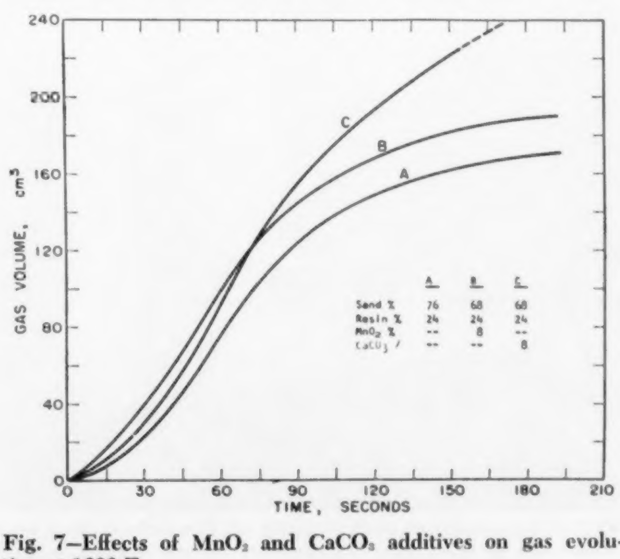

Fig. 7—Effects of MnO_2 and $CaCO_3$ additives on gas evolution at 1600 F.

Preliminary tests with a 94 per cent sand, 6 per cent resin mixture indicated a larger content of resin would be preferable. A mixture containing 76 per cent sand and 24 per cent resin was found suitable. When additives were used, the ratio of resin to additive was kept the same as previously used in shell-molding mixtures. Shell specimens were all made on one plate at the same time to insure exactly the same conditions of curing. These specimens were ground and well mixed to obtain good homogeneity.

Two grams of material were then used to run gas determinations. Three determinations were made on each material. Total gas evolution was measured at 1600 F, with time readings taken at every 20 cc of gas evolved. Data presented in Fig. 7 show that both manganese dioxide and calcium carbonate advance gas evolution.

TABLE 2 – ENTHALPY CHANGES IN THE DISSOCIATION OF CALCIUM CARBONATE IN THE PRESENCE OF CARBON AND HYDROGEN

Carbon Presence		Hydrogen Presence
(1) $CaCO_3 \rightarrow$	$CaO + CO_2$	$\Delta H^\circ = +41{,}800$ cal
(2) $CO_2 + C \rightarrow$	$2\,CO$	$\Delta H^\circ = +41{,}600$ cal
(3) $CO_2 + H_2 \rightarrow$	$CO + H_2O$	$\Delta H^\circ = +10{,}200$ cal

TABLE 3 – DISSOCIATION PRESSURE OF CALCIUM CARBONATE*

temp., C	Pressure, Atm.
550	0.00054
700	0.0292
800	0.220
898	1.000
906.5	1.151
937	1.770
1082.5	8.892

*From *Chemical Engineers' Handbook*, 3rd Edition, p. 174.

TABLE 4 – EQUILIBRIUM OF REACTION $C + CO_2 \rightleftarrows 2\,CO$*

temp., C	$\%CO_2$
500	95.0
600	77.0
800	7.0
1000	0.6
1200	0.06

**Reference Book of Inorganic Chemistry*, Latimer and Hildebrand, Revised Edition, p. 269.

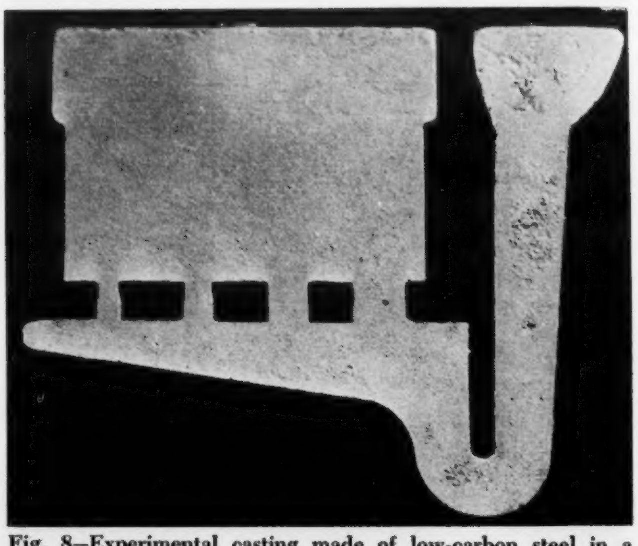

Fig. 8—Experimental casting made of low-carbon steel in a shell mold of silica sand blended with 10 per cent granulated limestone, poured at 2950 F.

It was also observed that swelling of larger castings occurred in molds containing manganese dioxide. The function of this additive appeared to be that of oxidation producing a more rapid breakdown of the resin structure. Other indications were that calcium carbonate, like forsterite, chilled the surface of castings. This effect was predominant. When the two additives were tested in molds made of zircon sand, results showed that calcium carbonate further improved the surface of castings while manganese dioxide made it worse.[2,5]

The chilling effect of calcium carbonate was thought related to its endothermic decomposition, and the further endothermic reaction of CO_2 with carbon from the resin binder. The molecular weight of calcium carbonate being about 100, reactions 1 and 2 of Table 2 indicate that in shell molds it would absorb roughly 800 cal per gram when the steel is poured. In comparison, the heat of solidification of steel is only in the order of 70 cal per gram. As indicated in Tables 3 and 4, dissociation of calcium carbonate would actively take place between 800 and 900 C. At this temperature level, the reaction of CO_2 with carbon would go almost to completion. Reaction of CO_2 with hydrogen could take place to a limited degree.

The effects of increasing amounts of manganese dioxide powder in shell molds have been studied previously.[1] Up to 4.0 per cent was used, and only slightly better results were obtained than when 2.0 per cent was used. Since oxidation appeared as the beneficial function of manganese dioxide, work was done with stronger oxidants and catalysts for oxidation reactions.

It was possible to obtain improvement over manganese dioxide in regard to the typical surface defects. However, the casting swelling difficulty was aggravated. This is apparently due to a rapid burnout of the resin bonds between the sand grains yielding of sand layers at the face of the mold under pressure of the metal. From a practical point of view, this phase of the work was inconclusive.

In the case of calcium carbonate, the chilling effect

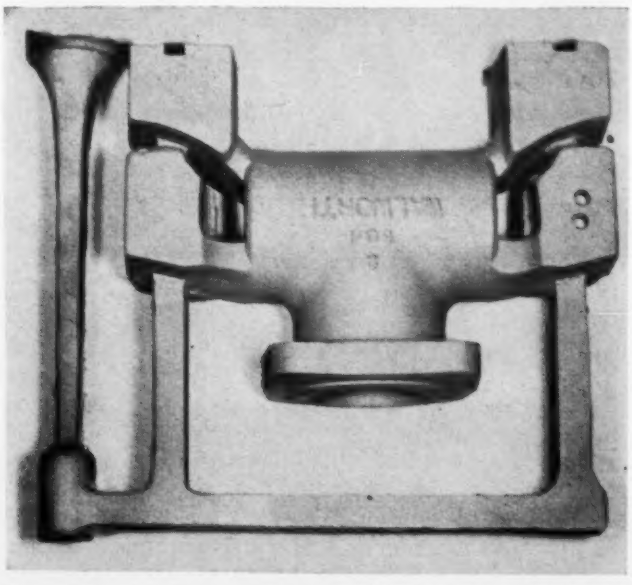

Fig. 9—Same casting as shown in Fig. 1 and 2, made with low-carbon steel in a shell mold of silicon sand blended with 10 per cent granulated limestone, poured at 2900 F.

would be directly proportional to the amount of additive present. This was investigated with molds containing increasing amounts of calcium carbonate powder up to 5 per cent. Great difficulties were experienced in making molds with more than 3 per cent powder. As expected, the casting surface condition gradually improved with successive additions of more carbonate. The problem of mold strength was solved by using granular material instead of powder. About 10 per cent granulated limestone was blended with silica sand to produce the castings shown in Fig. 8 and 9.

COMPOSITE SHELL MOLDS

Difficulty was experienced when using forsterite shell molds. This difficulty is—poor sharpness of detail on castings resulting from chilling and of non-wetting of molds by low-carbon steel. This can be best overcome by using composite forsterite molds having a thin facing of silica sand. These molds are made by a process of double investment which was previously described by the authors.[6] A casting made in a composite forsterite mold is shown in Fig. 10, for comparison with the one shown in Fig. 4.

In the case of granulated limestone-silica sand blends, there may be some trouble with metal penetration. This is particularly true when casting steels which have not sufficient chilling tendency. In general, this can be minimized by using finer limestone, and pouring without much superheat. However, best results are obtained by using composite shell molds with limestone in the backing only. Castings made in such molds are shown in Fig. 11 and 12.

Slight surface pitting is another difficulty which may be experienced. Pitting appears related more to segregation and degree of cure of the resin than anything else. The use of coated sand to prevent segregation, and of high pattern temperature to overcure the resin at the face of the molds, largely eliminates the pits. The pits are confined to the skin of the castings and cause little harm.

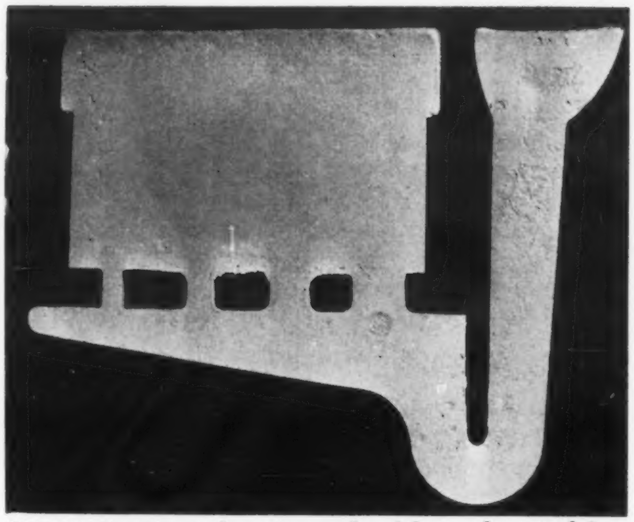

Fig. 11—Experimental casting made of low-carbon steel in a composite shell mold having a thin facing of fine silica sand and a backing of coarse silica sand blended with 20 per cent granulated limestone, poured at 2875 F.

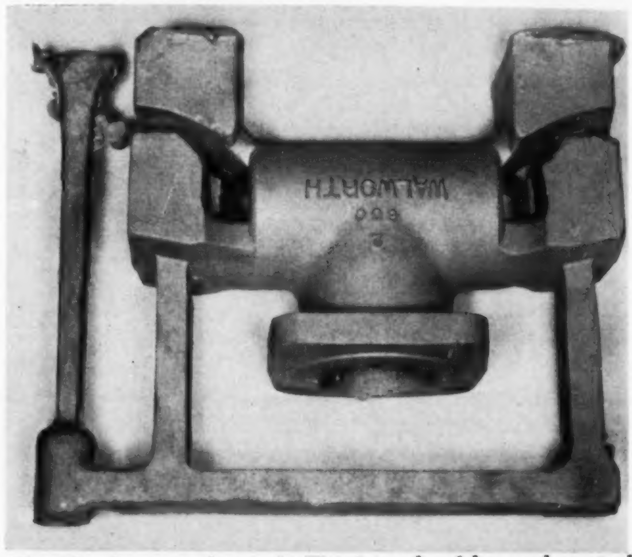

Fig. 12a—Same casting as in Fig. 1, made of low-carbon steel in a composite shell mold having a thin facing of fine silica sand and a backing of coarse silica sand blended with 20 per cent granulated limestone, poured at 2875 F.

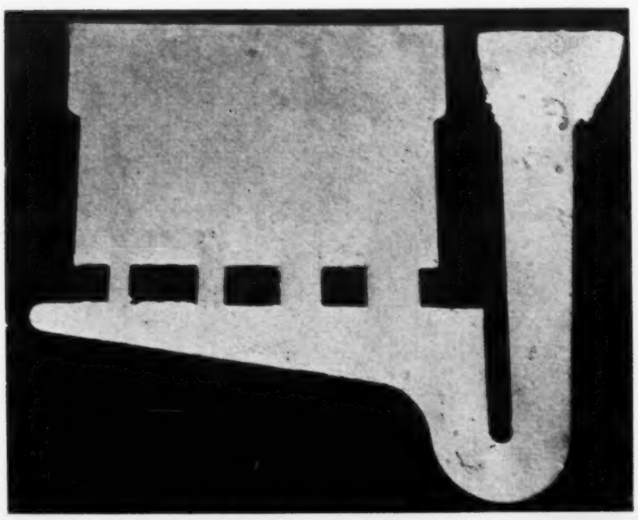

Fig. 10—Experimental casting made of low carbon steel in a composite forsterite shell mold having a thin facing of silica sand, poured at 2875 F.

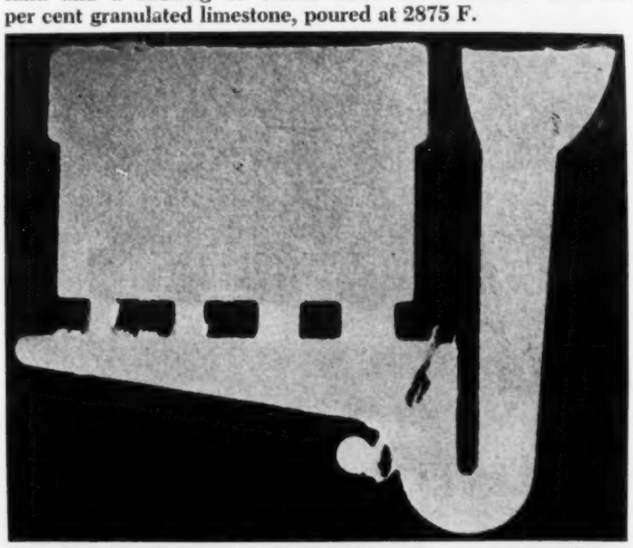

Fig. 12b—Experimental casting made of low-carbon steel in a composite shell mold having a thin facing of fine silica sand and a backing of 100 per cent granulated limestone, poured at 2950 F.

CONCLUSION

It has been shown that the surface defects generally occurring on low-carbon and low-alloy steel castings in shell molds can be eliminated by the use of chill-type shell molds. Such molds can be made with forsterite, or with simple blends of granulated limestone and silica sand. Best results are obtained when these materials are used in composite shell molds. These molds should have a thin facing of fine silica sand, and be made by a double investment process.

ACKNOWLEDGEMENT

The authors wish to thank Watertown Arsenal and the Department of the Army for sponsorship of this work. They would also like to express their appreciation to Professor Charles C. Reynolds and George E. Schmidt, Jr., for their cooperation and help.

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TENSILE PROPERTIES OF MICROSHRINKAGE-GRADED AZ-63 MAGNESIUM ALLOY

By

I. J. Feinberg and J. D. Grimsley*

ABSTRACT

Microshrinkage is damaging to the tensile properties of magnesium alloy AZ-63 casting material but little has been done to define the quantitative effects of the defect. A determination of tensile properties related to the degree of the defect obtained in radiographic classification is described. Quantitative determinations of ultimate strength, yield strength, and elongation values through statistical analysis of experimental data are discussed. Expected minimum properties for AZ-63 casting material containing six degrees of microshrinkage are presented.

INTRODUCTION

Reference radiographs which illustrate common defects in several degrees have been found to be valuable guides in the quality control of light-alloy castings. The Aeronautical Technical Inspection Manual (NAVAER-00-15PC-504), which has been compiled to fulfill the critical requirements for inspection of light-alloy aircraft castings is one of these guides. Quantitative tensile property data related to the gradient of the generally distributed defects illustrated in the manual are necessary in developing acceptance standards for particular casting applications. Microshrinkage is a defect for which tensile property data is required.

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LINE OF INVESTIGATION

This investigation was concerned with the determination of the tensile properties of sand-cast, heat-treated and aged AZ-63 material containing the common feathery or layer-type of microshrinkage. In its conduct it was essential to carefully control the factors other than microshrinkage which could have an effect on tensile properties. It was necessary to provide test material with a uniform type of microshrinkage, and a range of this type.

The determination of tensile properties was directly related to the severity in radiographic appearance of the discontinuity. Special emphasis was placed on the radiographic classification of the test material. Statistical methods were applied in reduction of the experimental data, because it was desired to obtain property values applicable to design.

NATURE OF MICROSHRINKAGE IN MAGNESIUM ALLOY AZ-63

The term microshrinkage is used interchangeably with microporosity among light-alloy foundrymen. It has been adopted in the nomenclature of the Aeronautical Technical Inspection Manual for the common layer-type of defect, SM 2.3. Since this investigation has been conducted in a phase of the radiographic standards project which produced the Manual, the term microshrinkage will be used in this paper.

Fig. 1—Microshrinkage types. 1a (left)-cloudy, 1b (right)-feathery.

Microshrinkage is due to unfed voids in alloys which solidify over a considerable temperature range. Gas in magnesium-base alloys causes a marked increase in the number of voids, but does not alter their characteristic form.[1] Microshrinkage is found to some degree in most magnesium castings. Radiographically, two forms of this defect are encountered: 1) a localized cloudy appearing dark area (Fig. 1a), and 2) the more common featherlike streamers (Fig. 1b).

The discontinuity is not generally dispersed as is gas porosity in aluminum castings, but localized in improperly fed areas.[2]

PREPARATION AND SELECTION OF TEST MATERIAL

Panels in which microshrinkage was synthesized were prepared in the following manner. Primary AZ-63 was melted down using a flux, and heated to 1400 F. One per cent of the flux was stirred through the melt. Each heat was raised to 1650 F for 15 min, then lowered to 1475 F, stabilized, sampled, skimmed, and poured. The panels were cast in a highly permeable silica-sand mixture containing 1.5 per cent sulfur, 2.0 per cent boric acid, 2.0 per cent bentonite, 2.5 per cent water, and 1.5 per cent diethylene glycol. Finally the panels were solution heat treated at 750 F for 12 hr, and aged at 425 F for 5 hr.

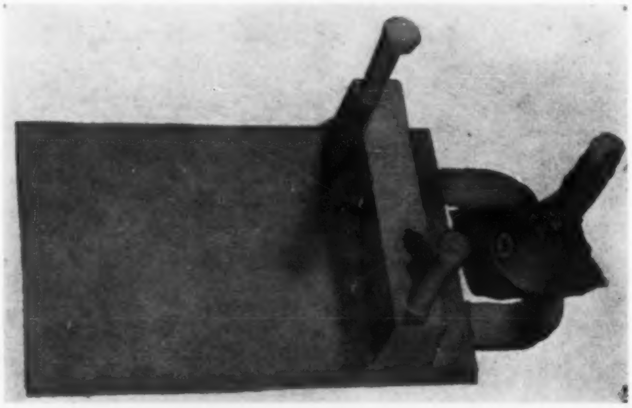

Fig. 2—Basic panel for test specimens.

Gradations in microshrinkage were obtained through variation in pouring temperatures and riser heights. These temperatures ranged from 1215 F to 1475 F. Riser heights of 1/2-in., 2 in., and 4-1/2-in. were employed. Figure 2 illustrates gating and risering used in producing the panels.

Because chemical composition, heat treatment, microstructure, and macrostructure affect tensile properties, variations of these factors were limited in the test material. Contaminating inclusions were avoided and the chemical composition was controlled for each heat. Secondary elements and impurities in the selected test material complied with specified maxima.

The aluminum content of test material ranged between 5.6 and 5.9 per cent, zinc between 2.6 and 3.1 per cent. Metallographic and microradiographic examinations were conducted to insure the use of material with a normal solution heat treated and aged microstructure only. Metallurgical examination of test slabs included checks for: a) Grain size, b) Massive compounds, c) Segregation, d) Microshrinkage distribution, and e) Contaminating inclusions.

Flat specimens with a reduced section of 3/8-in. × 1/2-in. were used to facilitate radiographic classification. In layout, the microshrinkage degree under test was concentrated in the center of the test specimen. To insure the proper fracture locale, it was necessary to limit microshrinkage in adjacent areas to a lesser degree of severity. Specimens were machined on all sides to eliminate effects introduced by the casting skin.

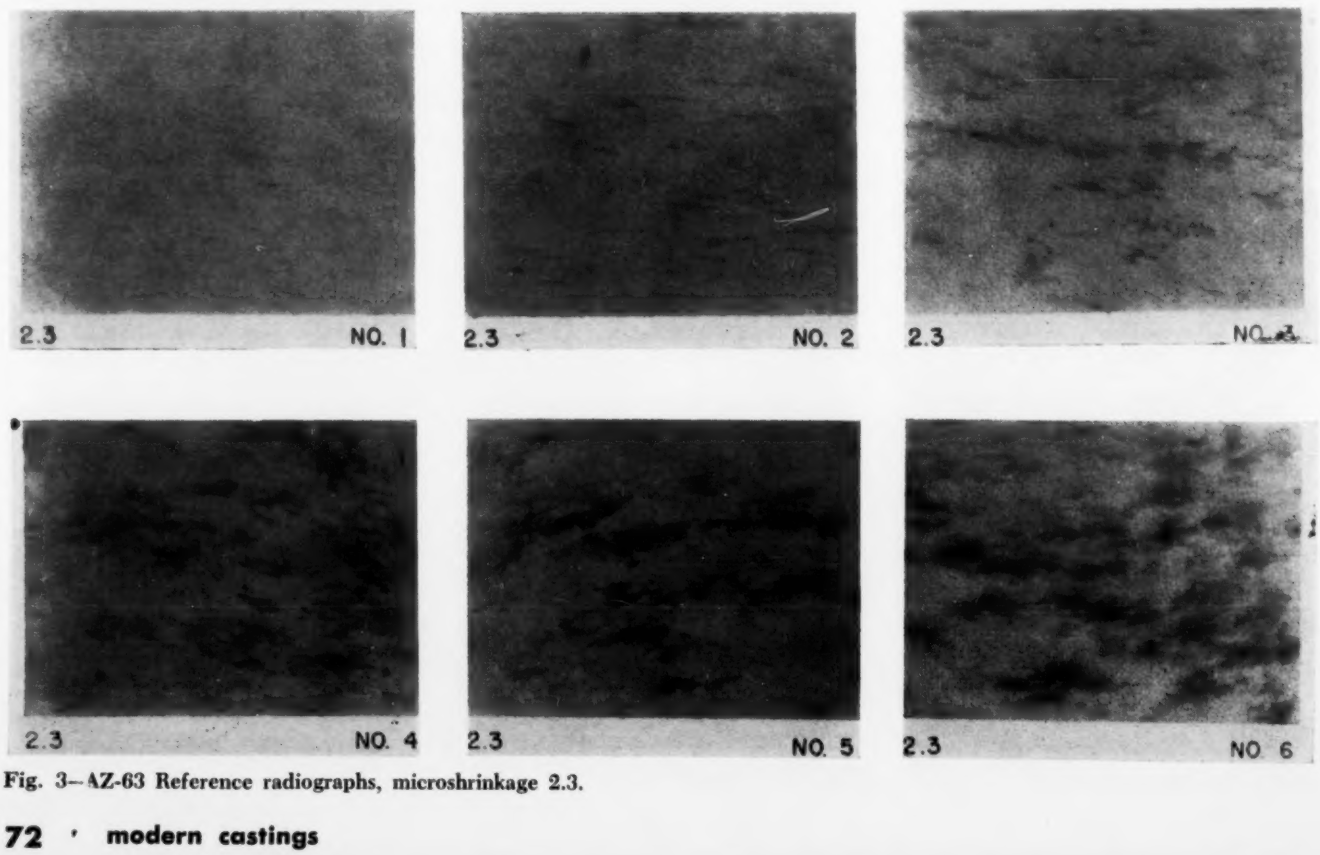

Fig. 3—AZ-63 Reference radiographs, microshrinkage 2.3.

RADIOGRAPHIC CLASSIFICATION

A photographic reproduction of the reference radiographs established for specimen classification is shown in Fig. 3. The radiographic illustrations for each grade were selected on the basis of their similarity to corresponding grades of microshrinkage, SM 2.3, illustrated in the Manual. These radiographs were obtained from 3/8-in. thick material, the same thickness as the test specimens. Type M film was used in the reference radiographs and in all test material radiographs. Exposure and development times were controlled to give a film background density of 2.0 ± 0.1.

Grade assignments for test specimens were based upon a consensus agreement of three interpreters. When interpretation differences exceeded two degrees, radiographs were regraded. The reliability attained with the AZ-63 standards is reflected in an average agreement of 96.5 per cent within ± one degree for 2,283 readings. Differences in agreement between interpreters are shown in Fig. 4. The tensile properties which follow depend on a ± one degree tolerance in grading.

DETERMINATION OF TENSILE PROPERTIES

Since microshrinkage is an aligned defect in magnesium alloy castings it was of interest to determine the effects of orientation on tensile properties. Accordingly, tests were conducted on one group of specimens in which the defect was aligned longitudinally to the principal axis of tensile bars and a second group in which it was aligned transversely.

Six microshrinkage degrees were investigated in each group. Stress-strain curves were obtained for each specimen tested. Yield strength at 0.20 per cent offset was determined from these curves.

Arithmetic means and their standard deviations were first determined (Table 1). While these observed means indicate a general decline in tensile properties with increase in microshrinkage degree, it can be seen from the standard deviations that the scatter between degrees is non-uniform. Individual degree means were obtained from small sample sizes (10 samples per degree). Since small samples are easily influenced by extreme values, better estimates of quantitative degree effects were sought from regression-correlation analyses using values for the total range of microshrinkage (degrees 1-6).

From the general equation for a linear regression,

$$y = a + b\,(x-\bar{x}) \qquad (1)$$

it is possible to predict values of y from values of x by calculating:

$$a = \frac{\Sigma y}{N} = \bar{y}$$

$$b = \frac{\Sigma\,(y-\bar{y})\,(x-\bar{x})}{\Sigma\,(x-x)^2}$$

$$\bar{x} = \frac{\Sigma x}{N}$$

Letting x = any degree of microshrinkage, y = mean property value for the degree x from the data, N = 60, the regression line equations in Table 2 were obtained. Analysis of variance of the data indicated that all properties except longitudinal yield strength are adequately represented by the straight lines which may be derived from these equations.

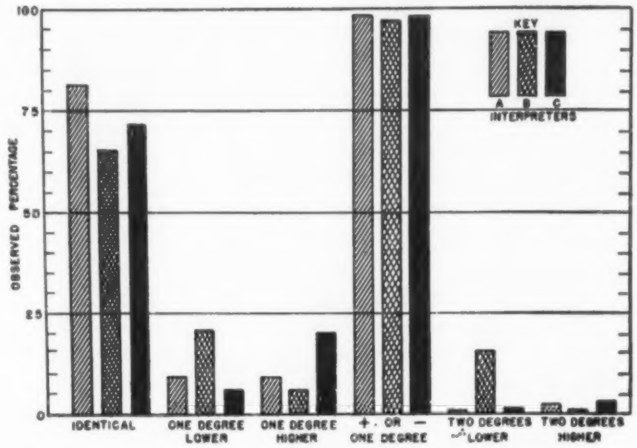

Fig. 4—Variance in readings from consensus assignment.

The 95 per cent confidence intervals for regression coefficients in Table 2 confirm the adequacy of fitted straight lines in relating certain properties to the degree of microshrinkage. Longitudinal and transverse ultimate tensile strength, per cent elongation, and transverse yield strength are subject to a linear relationship.

The regression coefficient for the longitudinal yield strength data is not significantly different from zero. In other words, here the regression-correlation analysis indicates no positive linear increase or decrease in longitudinal yield strength with increase in microshrinkage degree.

The unexpected nonconformity of the longitudinal yield strength data to a linear regression may be attributed to a large scatter occurring in sampling. This is coupled with the apparently slight over-all differences in damage in the range of microshrinkage

TABLE 1—MEAN TENSILE PROPERTIES AND SCATTER

	Ultimate Tensile Str.		Yield Str. 0.20% offset		Elongation in 2 in.	
Micro-shrinkage 2.3 degree	Mean psi	Standard Deviation psi	Mean psi	Standard Deviation psi	Mean per cent	Standard Deviation per cent
Longitudinal Alignment						
1	36,750	•3350	16,800	•1100	6.3	•2.0
2	37,500	•1800	18,500	•1200	5.6	•0.9
3	36,300	•2100	18,500	•1100	4.8	•1.2
4	34,200	•2050	18,300	•1250	3.8	•1.0
5	32,600	•2350	17,600	•1000	3.3	•0.6
6	32,400	•2050	17,900	• 400	3.4	•0.8
Transverse Alignment						
1	33,600	•3750	18,750	•1500	3.2	•1.4
2	31,300	•3050	18,400	• 800	2.3	•0.9
3	29,900	•2200	18,300	• 550	2.2	•0.8
4	27,500	•2150	17,650	• 500	1.7	•0.4
5	27,850	•2600	17,800	• 800	1.9	•0.7
6	26,400	•1900	16,950	• 800	1.6	•0.4

• equals plus or minus

TABLE 2 – REGRESSION EQUATIONS AND CONFIDENCE INTERVALS

Alignment	Property	Regression equation x = Micro-shrinkage degree	95% confidence interval, regression coefficient
Longitudinal	Ultimate tensile strength, psi	38,822 − 1106x	− 1110 • 360
Longitudinal	Yield strength psi	17,765 + 76x	+ 80 • 180
Longitudinal	Elongation, per cent	6.75 − 0.63x	− 0.63 • 0.18
Transverse	Ultimate tensile strength, psi	34,297 − 1394x	− 1390 • 400
Transverse	Yield strength, psi	19,126 − 330x	− 330 • 130
Transverse	Elongation, per cent	3.15 − 0.28x	− 0.28 • 0.13

• equals plus or minus

studied. There is little reason to believe that a curvilinear relationship would be adequate. No quantitative degree assignment would be meaningful for longitudinally aligned microshrinkage since the overall differences in damage are too small to identify with radiographic appearance.

The calculated means shown in Fig. 5-7 indicate that the severity of damage in properties due to microshrinkage is in descending order for the properties named. These properties are: elongation, ultimate strength, and yield strength.

This relative order of damage has been noted by Busk, Marande and Newhams.[3] They reported that the elongation of AZ-63 dropped from 15 per cent in sound test bars to 2 per cent in porous bars. Ultimate strength ranged from 41,000 to 17,600 psi, and yield strength from 13,500 to 11,500 psi.

In general, longitudinal orientation of microshrinkage is less detrimental than transverse. The approximate maximum reductions from longitudinal and transverse orientation, respectively, were: elongation, 49 per cent vs 50 per cent; ultimate strength, 15 per cent vs 21 per cent; and yield strength zero vs 9 per cent. Transverse alignment results in a relatively severe notch effect leading to stress concentration.

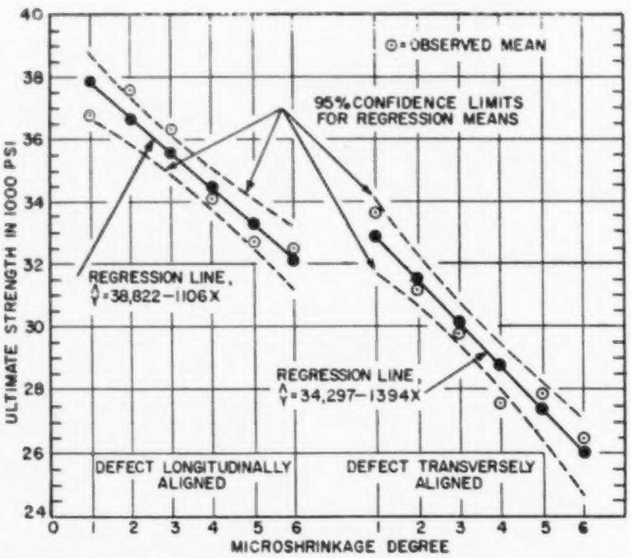

Fig. 5—Mean ultimate tensile strength.

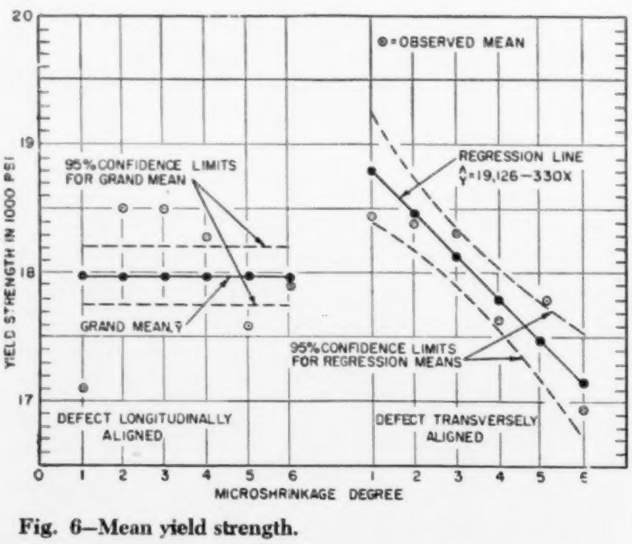

Fig. 6—Mean yield strength.

A given amount of transversely oriented microshrinkage results in a more reduced cross-sectional area for stress application. The greater damage from transverse orientation may be due to either or both of these two factors.

From the statistical standpoint regression means are to be found with a range; the greater the scatter in the population from which they are drawn, the greater this range. Thus confidence limits which fix the range of the means must be examined. To obtain confidence limits for those means found subject to a linear regression correlation, mean squared deviations of observed points from regression lines were calculated from:

$$\hat{\sigma}^2 = \frac{1}{N} \Sigma \, (y_{ij} - \hat{y}_i)^2 \qquad (2)$$

and

$$\hat{\sigma} = \sqrt{\frac{1}{N} \Sigma \, (y_{ij} - \hat{y}_i)^2} \qquad (3)$$

where N = 60, the total number of observations, y_{ij} = tensile property of j^{th} specimen at i^{th} microshrinkage degree, and y_i = estimated tensile property (point on regression line) for i^{th} microshrinkage degree.

Summation was carried out for j = 1, 2 . . ., 10 and i = 1, 2 . . ., 6. Then for a given microshrinkage degree, x_i, confidence limits for the calculated mean value of a tensile property, y, was given by an interval centered at y_i and parallel to the y-axis from the following equation:

$$\hat{y}_i \pm t \frac{\hat{\sigma}}{\sqrt{N-2}} \sqrt{1 + \frac{N\,(x_i-\bar{x})^2}{\Sigma\,(x-\bar{x})^2}} \qquad (4)$$

where N = 60, $\bar{x}$ = 3.5 and $\Sigma\,(x-\bar{x})^2$ = 175. Student's t = 2.00 for 95 per cent confidence limits with 58 degrees of freedom was used.

Confidence limits for the longitudinal yield strength mean were derived through determining first the standard deviation,

$$S = \frac{\Sigma\,(y_i - \bar{Y}^2)}{N-1} \qquad (5)$$

where $\bar{Y}$ = grand average of all yield strength observations, y_i = yield strength of an individual specimen, N−1 = 59. Then the 95 per cent confidence interval for the mean is obtained from,

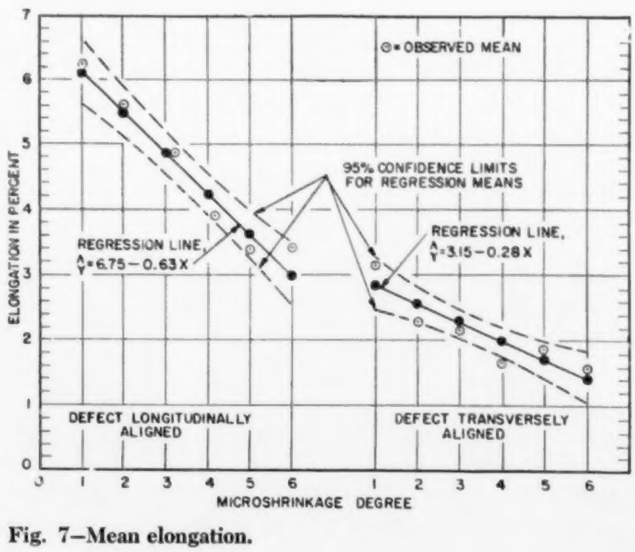

Fig. 7—Mean elongation.

$$\overline{Y} \pm \frac{ts}{\sqrt{N}} \qquad (6)$$

Student's $t = 2.00$ for 95 per cent confidence limits with 59 degrees of freedom was used. Confidence limits calculated in the statistical analysis are shown graphically in Fig. 5-7.

Minima

It may be predicted with 99.5 per cent confidence that tensile properties of an individual specimen at microshrinkage degree x will be greater than

$$\hat{y}_i - t\hat{\sigma}\sqrt{\frac{N+1}{N-2}} \qquad (7)$$

where $\hat{\sigma}$ is obtained from equation (3) and $t = 2.66$ for 58 degrees of freedom. For longitudinal yield strength with $\hat{\sigma}$ determined from equation (3), and $t = 2.66$ individual specimen yield strength at the 99.5 per cent, confidence level will be greater than

$$\overline{\mathbf{Y}} - \mathbf{ts}\sqrt{1 + \frac{1}{N}} \qquad (8)$$

Values calculated from these equations are the lower confidence limits for an additional observation at degree x. Minimum tensile properties which they represent are shown in Fig. 8-10.

These minima may be compared with requirements for AZ-63 in Federal Specification QQ-M-56. Material properties are related to separately cast test bar properties. For specimens cut from castings, the requirements are that the average ultimate strength, and average elongation of test specimens, shall be not less than 75 per cent and 25 per cent, respectively, of the value specified for separately cast test bars.

There is no QQ-M-56 yield strength requirement for material cut from castings. However, the aircraft industry has in many instances established its own yield strength requirements based on 75 per cent and 100 per cent of separately cast test bar yield strength. From Fig. 8-10, the materials which will meet the above requirements are as follows:

Ultimate Strengths

Degrees 1-6, Microshrinkage longitudinally aligned.

Degree 1, Microshrinkage transversely aligned.

Yield Strength

When 75 per cent yield value applies—Degrees 1-6 in both alignments.

When 100 per cent yield value applies—Degrees 1-2, Microshrinkage transversely aligned.

Elongation

Degrees 1-4, Microshrinkage longitudinally aligned.

CONCLUSIONS

Microshrinkage in magnesium alloy AZ-63 is detrimental to all of the tensile properties commonly used in acceptance criteria. It damages elongation severely, tensile strength moderately, and yield strength slightly. Transverse alignment reduces elongation and ultimate strength more than longitudinal alignment. Anamolously, longitudinal alignment was found to be slightly more severe on yield strength. Therefore, it is apparent that microshrinkage in castings should be evaluated with respect to its orientation relative to service stresses.

Reliable estimates of mean properties can be obtained through statistical analyses. Thus, fitted straight lines were found to be adequate in representing decreases in ultimate strength, elongation and transverse yield strength with increase in microshrinkage degree. The 95 per cent confidence limits, within which the true means were found, vary with the scatter arising

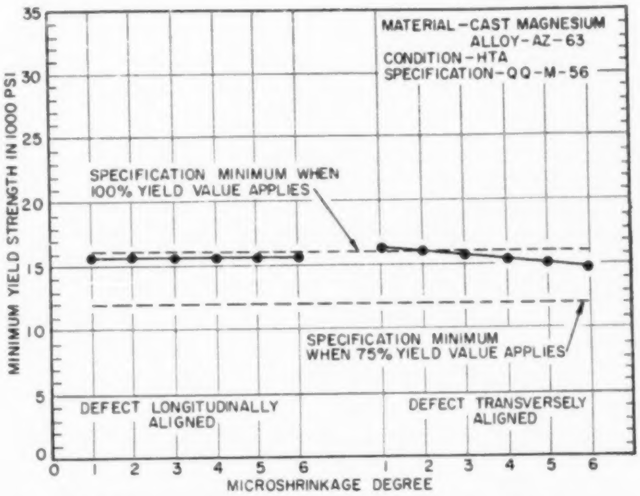

Fig. 9—Yield strength minima, 99.5 per cent prediction.

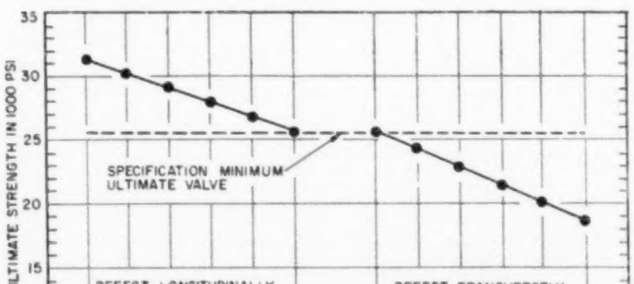

Fig. 8—Ultimate strength minima, 99.5 per cent prediction.

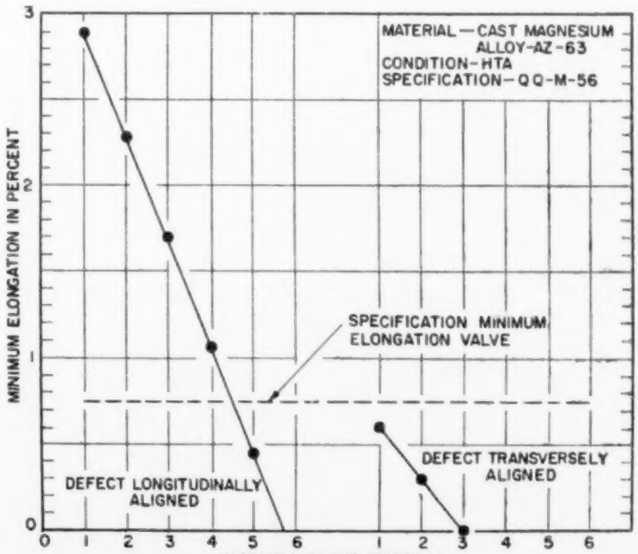

Fig. 10—Elongation minima, 99.5 per cent prediction.

from true radiographic assignment and inherent casting material variations. This scatter was within tolerable limits.

There is now considerable arbitrariness involved in radiographic specifications limiting the degree of microshrinkage allowable for particular applications. In overcoming this the application of an adequate strength level for highly stressed areas requires one approach. The economic utilization of inferior grades of material where property requirements are not stringent requires another approach.

In determining tensile property minima per degree, information needed in establishing realistic radiographic acceptance criteria for AZ-63 material has been provided.

Basic machined material properties were sought in this investigation. The values are directly applicable to limited areas of a machined casting. They could be considered slightly low when applied to entire castings. Machined specimens exhibit slightly inferior properties compared with those containing the original casting skin.

The fact that the properties presented are from machined material must be taken into account when they are used to evaluate the potential of entire casting areas. Section size should also be considered in application of the values. The properties were obtained from 3/8-in. thick material. Differences may be expected from material thicker than 3/8-in. Section size, an important property determinant in sand castings, within practical limitations, is considered to affect properties in much the same manner as casting defects.

The preparation of the radiographic Manual (NAVAER-00-15PC-504) was a preliminary step taken toward the improvement of light alloy casting quality standards. Quantitative data concerning the influence of various defects are required as additional bases for this effort. The tensile property values presented are intended to fill a gap now due to the lack of quantitative data for microshrinkage in magnesium alloy AZ-63.

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THE USE OF OIL-BENTONE SAND FOR HIGHER QUALITY FINISH IN BRASS AND BRONZE CASTINGS

By

O. E. Johnson*

This paper is presented as a comparative study of bentonite-water bonded sand as formerly used versus oil-bentone bonded sand as presently used for the past twenty months. This is a study and observation of the advantages and disadvantages of each, particularly of the oil-bentone sand as used by the author's company in its non-ferrous foundry regarding mixing, molding, shakeout, casting quality and cost.

A brief description of the foundry, its layout, equipment, and type of castings produced might be helpful in visualizing methods used in preparing and using the oil-bentone sand under discussion.

First, the company operates a captive foundry, semi-mechanized in operation, and containing four molding stations with overhead sand (Fig. 1). This sand is prepared in a muller, then discharged upon a conveyor. It then goes to an elevator where it is aerated and discharged into the molder's hoppers. The molds are made on conventional jolt-squeeze machines (Fig. 2), where the completed molds are placed and lowered pneumatically for pouring (Fig. 3). The weights are raised and lowered pneumatically for pouring. All metal is melted in a lift coil 100 kw high-frequency furnace with a 70 size crucible.

The flasks used are steel, 11 x 18 in., with 3-in. cope and 3-in. drag. Other flasks used are 12 x 16 in. with 3-in. cope and 3-in. drag.

Metal poured per mold averages 6 lb, gross. The average casting is 12 pieces to the lb. All castings are polished, buffed, and lacquered. Many castings are also plated. No visible defects are accepted on saleable castings. The line manufactured is builder's hardware. All foundry operations are performed in an area of 4,900 sq. ft.

Clay-water bonded sands are still being used by most foundries, and in the future they probably will continue to be used. Their use is well understood, and each foundryman has his particular mix or mixes that have given him satisfactory casting quality. It is not the purpose of the writer to go into the merits of these, but rather to discuss what has been done with oil-bentone sand by the author's company.

Many sands may be used depending on the finish desired, but they must be of the washed and dried variety. In this type of bonded sand, water, clay, or volatile materials are to be avoided. Water has always been a necessary evil in molding sand. Oil-bentone sand does not use water; therefore permeability becomes less of a factor. There are less gases evolved in pouring of oil-bentone sands. Sand fineness can be increased to the point where it is difficult or impossible to remove clay or silt (about 180 AFS).

Molds may be rammed harder with no danger of scab or wash, giving a more accurate mold cavity and a closer tolerance in casting dimensions. Due to the absence of water, fluidity of the metal is increased. The chilling effect of water is eliminated.

This may create a shrinkage problem. Shrinkage is not increased, but becomes more visible because a thinner skin on the casting allows the shrinkage to become surface rather than internal in nature. A change in gating or risering may be necessary in some cases.

Surface finish is more easily maintained with the oil-bentone sand. This is not meant to infer that good

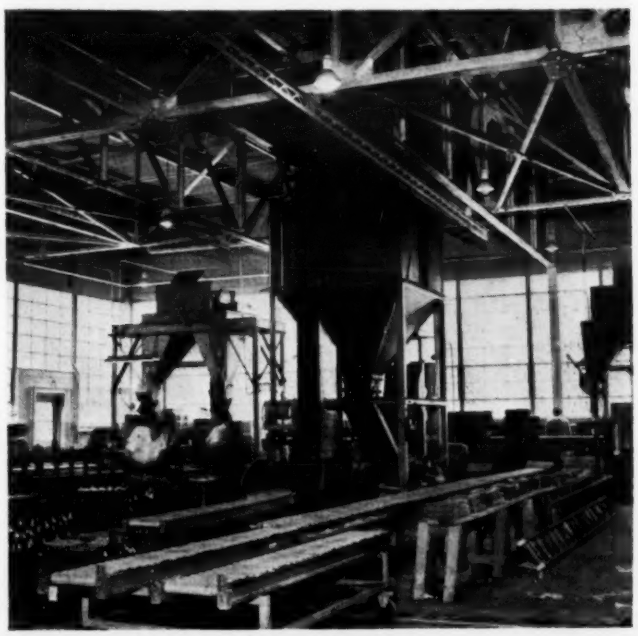

Fig. 1—View of the 4-station molding bay.

*Foundry Foreman, The H. B. Ives Co., New Haven, Conn.

finish is unobtainable with clay-water bonded sand, only that the author's company is able to produce a consistent good quality of finish now. The finish produced formerly was not consistently good.

Since the adoption of oil-bentone bonded sand, extra wheel operations and repair operations in the polishing department have been greatly reduced. Prior to its use they were frequent enough to be considered standard.

This sand seems to have better ability to flow or to conform to pattern contour than the sand formerly used. It is felt that the casting finish now is as good as in shell molding, with the advantage of being able to use standard foundry equipment and methods.

While the bonding and wetting materials are more expensive, they are not as expensive as the materials used in shell molding, and the sand has the advantage of being reusable. It is not even necessary to remull after each use, aerating being adequate.

However rebonding should be done in the muller. As to the rebonding process, it is difficult to be specific as to frequency or amount of new bonding material to use. The ratio of sand in the mold to the volume of metal poured, plus metal temperature plus time allowed before shake-out, determine the amount of bond and the frequency of rebonding. As long a time as is practical between pouring and shake-out is advantageous, as the oil has a chance to recondense in the sand rather than be drawn off by the exhaust system as vapor.

Hot sand does not seem to be a problem. It does not stick to the plate, provided no wax is present. There has been no tendency to wash or scab regardless of mold hardness. It is a bit more difficult to move in the system, but by reducing the amount of sand to be moved, as temperature is no problem, the moving of the sand becomes less difficult.

As far as records and methods of testing the sand are concerned, the writer believes that the user of oil-bentone bonded sand must determine for himself the proper hardness, permeability, green strength, and dampness. No water being present, permeability becomes less important. Oil instead of water complicates determining moisture content. The feel and response of the oil-bentone sand is quite different from clay-water sand.

It is practical to use at an apparent green strength unthinkable with clay-water sand; for example, 3 lb green strength. Also, 8 to 9 lb green strength is the maximum practicable to obtain. This strength is not necessary and makes molding more difficult. It seems to have more ability to be compressed than clay-water sand. Green strength of 5 lb and mold hardness of 75 will make most jobs, give a fine finish, and close dimensional tolerance.

The bonding method is well described by the manufacturer. To repeat briefly, all measured amounts should be accurate by weight and washed, and dried silica sand, fineness as desired. Dry bond is added, and it is put in the muller. Oil is added immediately, and mulled for 2 min. Ethyl or wood alcohol is added and it is mulled until the sand is ready to use; that is, until the oil-bond-alcohol reaction has taken place. This is usually within 6 or 8 min. after adding alcohol, with the high-speed muller. In bonding, the muller is a must.

At the author's company there is no laboratory or a man responsible for compiling sand or metal data. However, there is equipment for testing mold hardness, green strength, permeability, and moisture. Two sands are used—one with a grain fineness of 155 AFS; the other about 190 AFS.

Using the 155 sand and adding 3.5 per cent bentone, 2.5 per cent oil, and 1 per cent ethyl alcohol, mulling as described, the figures A in Table 1 were obtained. Using the 190 sand and adding 4 per cent bentone, 3 per cent oil, and 1.5 per cent alcohol, mulling as before, the figures B in Table 1 were obtained.

The writer feels that it is fair to conclude that almost any desired green strength may be obtained by

Fig. 2—Molds are placed on a roller conveyor for pouring. Weights are handled pneumatically.

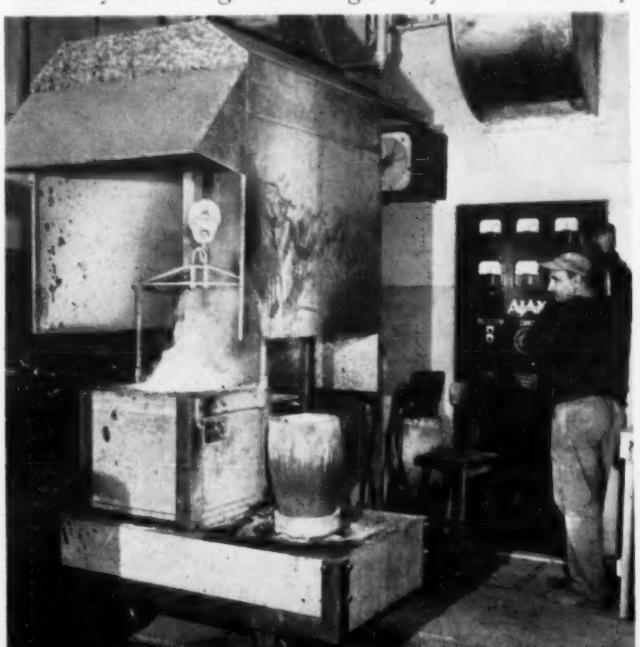

Fig. 3—Metal is melted in a lift-coil 100 kw high frequency furnace.

TABLE 1—SAND MOLD HARDNESS, GREEN STRENGTH, AND PERMEABILITY, 155 SAND

	Mold Hardness	Green Strength	Permeability
A	70	5.5	20-25
	85	8.5	12-16
B	80	8.5	12-16
	90	13.0	10

increasing mold hardness and varying the amounts of oil and bentone. Permeability decreases as mold hardness or oil increases. However, permeability is not an important factor with oil-bentone sand. The writer further feels that while these figures may serve as a guide in starting to use this type of bonded sand, in the final analysis each foundryman must develop that sand and procedure which best fits his needs and equipment.

Rebonding, ideally, in the writer's opinion, should be done by adding small quantities of oil, bond and alcohol to each muller load. However, rebonding is not done in this manner. A green strength of 8 lb is obtained. This is allowed to reduce by use to about 3 lb green strength, then approximately 15 per cent of the original amount of oil is added to bring up the moisture content.

It is then allowed to become weak by use again, at which time about 20 per cent of oil, bond and alcohol are added, bringing the sand back to 8 lb green strength. This requires somewhat longer than the regular mull cycle, but about 25 per cent of the bonding cycle.

Certain precautions should be taken. First, the muller door, if it is the enclosed type, should be left open after the alcohol has been added. This is explosive as well as toxic. No smoking or fire should be allowed near the muller during bonding or rebonding. The alcohol should not be allowed to remain in the plant except during use.

No further hazards are encountered until the poured molds reach the shakeout. Here the molds must not be shaken out until the castings have cooled to a temperature where the oil vapor will not ignite, otherwise a flash fire will occur. The shakeout should be hooded and ventilated to remove the smoke and vapor released. No other hazards have been encountered.

Bentone is a dry powder, produced from bentonite by a chemical conversion. It is combined with metal oxides for use in the foundry. In fineness it compares with bentonite. Its ability to combine with oil to produce a bonding action with sand makes it ideal for use in formulating foundry molding sand.

The oil used is a gulf coast oil with a viscosity of 100 at 100 F. It is similar to a flushing oil, and has a high flash point. It is obtainable at any oil company. The alcohol must be ethyl or wood. No substitutes, to the writer's knowledge, are acceptable.

The following figures, taken from the accountant's records, covering the year 1955 (the year clay-water bonded sand was last used) and 1957 (the first complete year oil-bentone sand was used) are presented for the consideration of the reader. It has been found that the oil-bentone sand costs 1.65 cents more per lb of good castings produced.

This added expense can be justified because of the use of castings which require a highly finished surface. Approximately two-thirds of all castings produced are by tumbling methods. The better surface and the thinner skin now obtained allowed a reduction in the tumbling cycle by one-third, thus increasing the potential capacity by 50 per cent.

Unfortunately, the need for this added capacity cannot presently be foreseen, therefore, a savings has not been calculated, for unless volume unexpectedly increases, the savings will not be realized until existing equipment needs replacement.

The other third of the castings produced are finished by hand polishing methods. This is where tangible cost savings have been realized. The cost records for 1957 (the oil-bentone sand period) indicate savings in polishing labor and other direct costs (excluding all fixed overhead costs) amounting to 14 times the additional foundry costs. These data were computed by comparing years 1955 and 1957 on the cost per lb of good castings basis.

It would be erroneous to assume that the new sand procedure should have the entire credit for this savings. For, as the comparison necessarily embraces a three-year period, several other changes of a technical and supervisory nature also occurred during this time. It is believed, however, that at least half of this improvement can be directly attributed to the use of oil-bentone bonded sand. Therefore, the author's company feels justified in continuing the use of this sand.

Somewhat in the form of a bonus for the company, it is easy to use. It gives a consistently fine finish and closer tolerances. It peels almost completely from the castings, and uses far less new sand additions. It needs no special equipment, is easier to control (in the writer's opinion), gives a thinner skin to the castings, and aids the metal in filling the mold cavity because of a lesser chill effect.

The decision to use this sand was made with some hesitation because it meant a complete discarding of the clay-water bonded sand and replacing it with oil-bentone bonded sand. It further was felt that at least one year's trial was necessary to get as accurate an appraisal as possible of its benefits, costs, and other information.

The writer feels that without a competent cost accountant and cost system with accurate records, this report would not have been possible.

ACKNOWLEDGMENT

The writer also wishes to thank all members of the company for their help and encouragement in the preparation of this paper.

DUST PIPING MODIFICATIONS TO PREVENT MATERIAL BUILDUP AND WEAR

By

R. C. Ortgies*

In modern industrial plants, equipment manufactured by numerous companies is blended together to perform as a single unit to produce an end product. Each of the components must of necessity be of the highest quality and workmanship, precision manufactured, and designed for a minimum amount of maintenance. This was achieved through: 1) Research, 2) Engineering, 3) Field application data, 4) Material selection, and 5) Manufacturing techniques acquired through years of experience.

Such a combination occurs in foundries, particularly in sand handling and shakeout systems, abrasive cleaning, polishing and grinding stations. All foundries are dust control conscious; therefore, suitable equipment has been installed to prevent contaminants from being discharged to the working area and to the atmosphere. The main link between the manufacturing equipment and dust control is the dust piping system.

During the past 20 years and more, little or no improvement has been made in the dust control piping system except for the following:

1. Standardization of gauge thickness of metal piping.
2. Design specifications for hooding at conveyor transfer points, enclosures, etc.
3. Minimum and maximum velocities through hood openings.
4. Standardization of conveying velocity requirements.
5. Standards for calculating air volumes and duct resistance.

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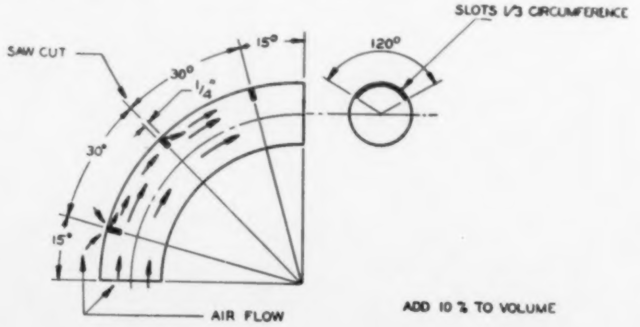

Fig. 1–To eliminate plugged elbows cut 1/4-in. slots in the outer surface for a maximum of 120 degrees. A minimum of three slots are required for a 90 degree elbow.

Too often the main concern of engineers in the dust control field, as well as the fabricators and installers of the duct work systems, is to comply with good piping practice which consists of proper sizing of all ducts, the use of long radius elbows, proper location of branch pipes to the main ducts, and provision of cleanout doors and blast gates to regulate air flow. However as dust loads increased with high-speed production, it became apparent many foundries did encounter wear at elbows due to heavier dust loads, plugging due to moisture, and plugging from handling materials of a tacky nature due to impregnation with grease or other materials.

A dust piping system to be effective for today's requirements must have, in addition to compliance with fixed regulations, elbows which eliminate wear and plugging; duct connections which are readily removable. A system must be designed to eliminate plugging where moisture laden air and dust is handled. In many applications corrective measures should be taken where material which is semi-fluid or greasy is carried in the air stream. Proper placement of duct connections with large transitions is desirable.

Some 10 years ago introduction of the flat-sided elbow was an initial step toward helping the abrasive problem (same as Fig. 2 except for slots). For extreme dust loads the wearing side was rubber lined in some cases.

Duct modifications to decrease maintenance and corrosion which have been proved in the field in foundries and allied industries are as follows:

ELBOWS

When abrasive, semi-fluid, greasy, or moisture-laden air and dust pass through an elbow, the dust is forced to the outer surface by centrifugal force. If abrasive, holes soon appear. If moisture and dust, a plugged elbow results. To eliminate or reduce these effects, it is necessary to prevent the material from making contact with the outer surface. This can be accomplished by saw cutting 1/4-in. slots in the outer surface for a maximum radius of 120 degrees. A mini-

mum of three are required for a 90 degree elbow (Fig. 1) placed at 15, 45, and 75 degrees, respectively.

The indraft air raises and deflects the dust preventing contact with the outer perimeter of the elbow. Where flat-sided elbows are used, the above procedure is carried through on the outer flat plate only (Fig. 2). Additional air required to compensate for slots is approximately 10 per cent of volume passing through each elbow for small diameter pipes, with lesser percentage for larger sizes. While volume through slots is a function of the total pressure in the ducts and the duct diameter, it will approximate an additional 10 per cent of the exhaust volume.

SAND MIXER VENTILATION

Where moisture laden air and dust is vented from a process such as a sand mixer in a foundry to a central or individual dust control system, plugging of ducts often occurs. This generally occurs at hood or enclosure duct connections and elbows in the branch line. Continual cleaning of such ducts can be reduced or eliminated by bleeding in room air at a point above the hood (Fig. 3). If a 7-in. pipe is required for efficient ventilation, a flanged duct 9 in. in diameter should be used for the bleed-in method. The 7-in. duct should extend into the larger pipe a minimum of 6-in.

This concentrates the moist air from the hood through a column of relatively dry air. Since no contact is made with the pipe, plugging is retarded or eliminated. Eventually, mixing occurs and in some instances the bleed-in method must be repeated. It is advisable to use the slotted elbows in conjunction with this system wherever turns must be made in the duct line. In most instances one elbow is all that is required before entering the header pipe. Approximate air volume requirements are 25 per cent of original volume calculated. To facilitate cleaning of the short riser, it is suggested that construction should provide means for easy fast removal. Use larger round tapered 45 degree transitions wherever possible.

AERATOR VENTILATION

Where moisture content and dust loads are not too severe, a system where lesser quantities of bleed-in air are required can be installed. By placing 1/4-in. slots around the circumference of the branch pipe using three 90 degree open areas, the bleed-in air through the pipe will help eliminate plugging of the duct (Fig. 4). The remaining three 30 degree uncut areas are retained to steady the pipe. A second row of slots spaced 2 or 3 ft beyond the initial set is helpful for more severe cases. The slotted opening should then be rotated 30 degrees for best results. Ten per cent of duct volume for each row of slots is the usual requirement.

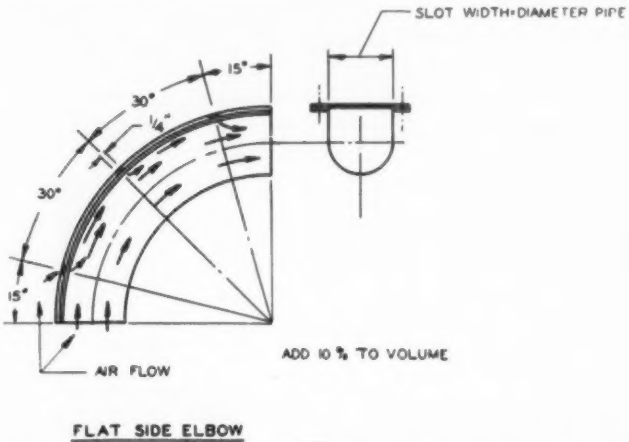

Fig. 2—When flat-sided elbows are used, cut slots through the outer flat plate only.

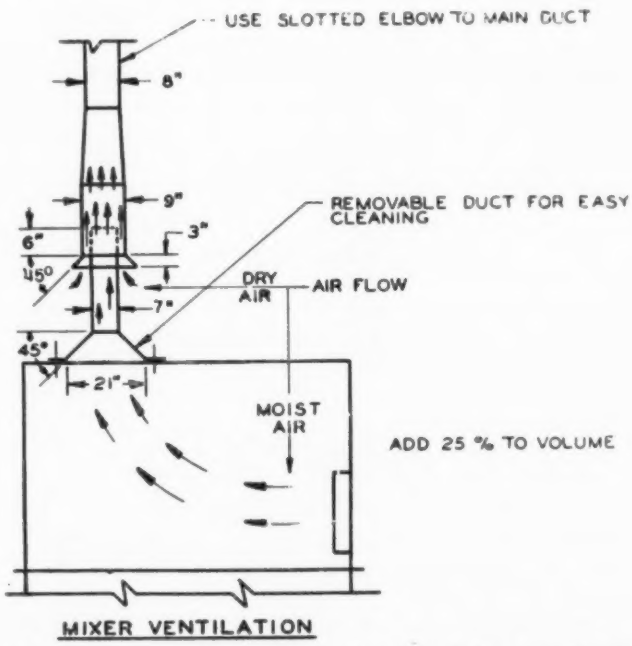

Fig. 3—Continual cleaning ducts of a central dust control system can be reduced or eliminated by bleeding in room air at a point above the hood.

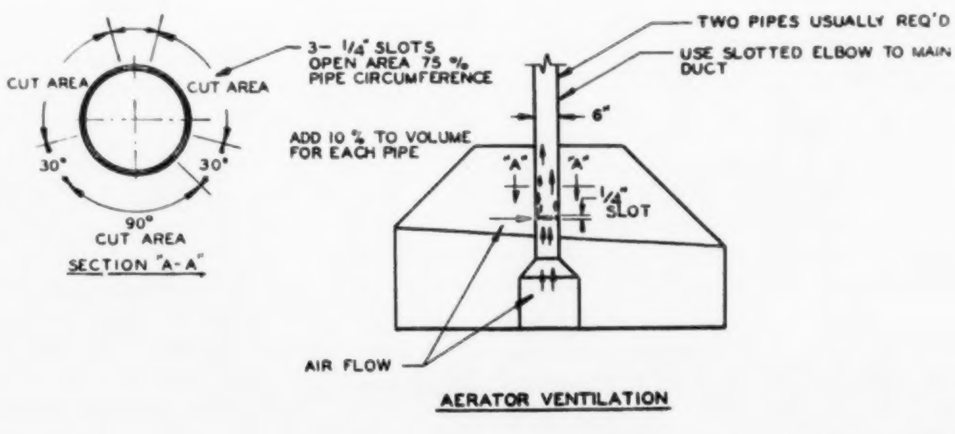

Fig. 4—By placing 1/4-in. slots around the circumference of the branch pipe using three 90 degree open areas, the bleed-in air will help eliminate plugging of the duct.

ELEVATORS

Elevators, because of their height, often are victims of improper placement of duct connections. A common error is to install the ventilation duct on the head of the elevator discharge chute.

An elevator operating at maximum capacity generally throws the sand past the duct. It is only logical that large quantities of sand will be drawn into the dust control system with the exhaust air. Plugging and excessive pipe wear results. Heavy concentrations from improper location is often a factor where slurrying is encountered in wet-type collector sludge tanks.

The proper choice is either the side or top connection. In replacing belts the top connection usually interferes and must be disconnected. Too often the temporary removal becomes a permanent feature resulting in complete loss of contact at this point. A simple slip joint can be used to advantage to reduce time and cost of replacement. Many of the newer foundries are using side connections as this causes no interference with elevator repair work. Basic dimensions for proper side plenum are shown in Fig. 5. If hot or steaming sand is encountered and excessive condensation is occurring, causing plugged ducts, the muller type of connection, Fig. 3, used in conjunction with slotted elbows usually eliminates entirely or reduces this branch pipe difficulty.

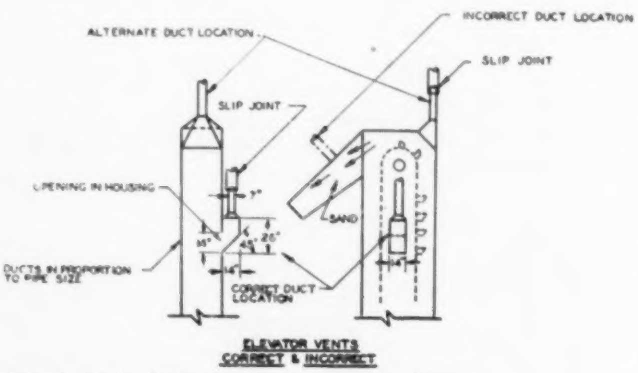

Fig. 5—Basic dimensions for proper side plenum.

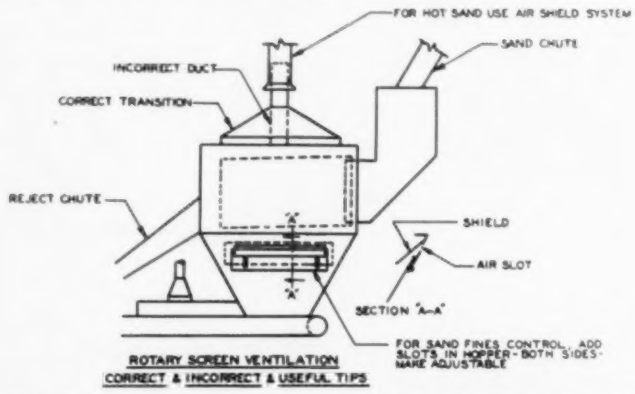

Fig. 6—A large transition reduces velocity and eliminates sand carry over.

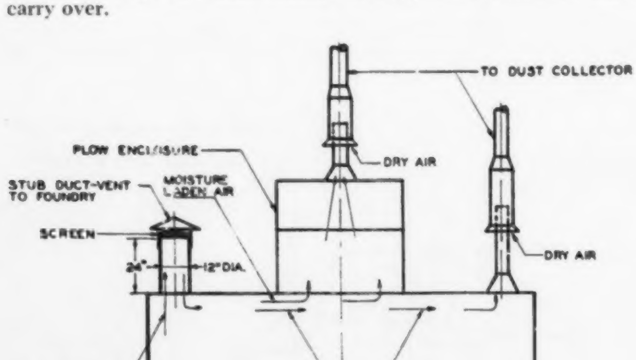

Fig. 7—Proper foundry venting by a stub stack overcomes condensation formation in bins.

ROTARY SCREENS

Rotary screens, as a general rule, are hooded fairly close by the manufacturers to the rotating drum. Too often the venting duct connection is made without the use of transitions. If provided, they generally are too small to obtain maximum dust control without carry over of valuable sand to the collector. Sand clinging to the screen when passing the duct is carried away by the high velocity air movement. Excessive duct wear and plugging results. Heavy dust loads to collectors which causes excessive maintenance can be traced to improper connections.

A large transition of the type as shown in Fig. 6 reduces velocity and eliminates sand carry over. Where it is desirable to remove fines, louvres installed in the hopper section aid in this respect. These should be adjustable (Section "AA" Fig. 6). Where hot steaming sand is encountered and branch pipe plugging occurs the use of air shield systems in combination with slotted elbows are aids to be considered to eliminate this malfunction.

SAND BIN VENTILATION

Bin ventilation standards have been established and are in general usage today. Little has been written on methods to prevent condensation during shutdown periods. With sand system and dust control units in operation the bins are under a negative pressure. Extreme cold, damp, or humid influx of air causes condensation to form within the bin. This can be overcome by venting to the foundry proper by the use of a stub stack (Fig. 7). Conditions within the foundry at top of sand bin tower approximate those within the bins more closely than outside temperatures and weather. Vent should be equipped with sloping guard and inlet screen. Where production has increased the sand cycle hot sand results. Conditions are then more difficult than where bins of ample capacity are used. Satisfactory results have been obtained by doubling the amount of stub vents and utilizing the muller type of connections.

This discussion deals primarily with foundry applications where each of the six methods shown has been successfully used.

Other industries having similar problems, could cut their maintenance labor and duct replacement costs by intelligent use of similar exhaust system modifications.

Piping must be kept clean and free from all obstructions if the system is to contribute to the health and welfare of production workers, reduce fire hazards, and lower maintenance costs both to machinery and the collector proper.

PACKING CHARACTERISTICS OF TYPICAL FOUNDRY SANDS

By

L. J. Pedicini*

The previous papers of this symposium have described the laws governing the compaction of small particles and to what extent single sieve fractions of foundry sands comply with these laws. This paper deals with the compaction of some typical foundry sand distributions. Table 1 lists the 11 sands included in this study. They were selected solely on the basis of availability at the time. However, they cover a rather broad range of finenesses and distributions, as shown in the sieve analyses listed in Table 2.

VIBRATED DENSITY – DRY SAND

The dry density of each sand was determined by vibrating one quart of the material for 45 sec. The equipment used is shown in Fig. 1. It consisted of a standard one-quart container which had been fitted with a sleeve that extended 1-1/2-in. above the top of the container.

*Head, Metal Castings Laboratory, General Motors Process Development Staff, Detroit.

TABLE 1 – TYPICAL FOUNDRY SANDS STUDIED

Name	Type	AFS Fineness	Screen Distribution	Specific* Gravity
1. Muskegon Lake	Subang	51.4	4	2.61
2. Silica No. 60	Round, Subang	34.4	2	2.63
3. Wedron No. 8	Aug. Subang	111.2	3	2.65
4. Wedron No. 10	Aug. Subang	144.4	3	2.63
5. Juniata Shell	Aug. Subang	116.3	4	2.56
6. Zirconite	Aug. Subang, Round	118.7	2	4.76
7. Wedron No. 2	Subang	51.7	3	2.63
8. Vassar Bank	Aug. Subang	94.2	3	2.60
9. St. Marie Shell	Aug. Subang	117.5	4	2.65
10. Penn Glass	Aug. Subang	141.7	5	2.61
11. Manley Silica	Aug. Subang, Comp.	160.8	5	2.63

*Experimentally determined

Fig. 1–Equipment used for vibrated density determinations.

The sand was dumped into the container to the level of the top of the sleeve. The container and its contents were then placed in the vibrating fixture and vibrated for 45 sec. A one-in. pneumatic vibrator was used. After the vibration, the sleeve was removed and the sand was struck off level with the top of the container. The tared weight of the sand was recorded for the density calculations. Averages of five tests are recorded as the vibrated dry densities in Table 3.

It should be noted that all densities in this paper are expressed as percentages of the experimentally determined specific gravities as shown in Table 1.

It was determined that the vibrated dry densities of the sands studied were all within ± 10.3 per cent of the theoretical orthorhombic packing (60.45 per cent solids). The deviations from the theoretical can be attributed to imperfect packings, grain shapes, light and/or heavy impurities, grain size distributions, and experimental error. However, it can be assumed that most foundry sands will approximate orthorhombic packings, at least in the dry state.

Further study of the data indicate that coarser sand, as defined by the AFS fineness number, packs to greater density than finer sands. This is shown graphically in Fig. 2.

RAMMED DENSITY – DRY SAND

The rammed densities of the 11 test sands were determined for 1, 5, 10, 15, and 20 rams using the standard AFS equipment and procedure.* The density calculations were only approximations based on the weight of sand in a 2-in. x 2-in. diameter specimen. The results are shown with the vibrated dry densities in Table 4. This data follows the same general trend as shown in Fig. 2 for vibrated densities.

It is interesting to note that only four of the sands (2, 7, 8, and 10) attained higher densities at 20 rams than were attained by vibration. Moreover, only sand No. 7 attained a significantly higher density by ramming.

*The procedure is described on pp. 21 and 22 of the Foundry Sand Handbook, American Foundrymen's Society, Des Plaines, Ill.

TABLE 2 – SIEVE ANALYSIS OF SANDS TESTED

U.S. Sieve No.	Per Cent Retained on Screen for 11 Sands Tested										
	1	2	3	4	5	6	7	8	9	10	11
20	0.22	–	–	–	–	–	–	–	–	–	–
30	2.68	5.40	–	–	–	–	–	–	–	–	–
40	13.70	59.90	–	–	–	–	–	0.62	–	–	–
50	33.22	27.56	–	–	1.52	–	34.12	1.86	3.00	1.60	1.08
70	31.20	5.08	2.80	–	4.82	0.32	48.50	8.04	5.18	9.08	6.42
100	12.28	1.30	20.40	3.54	20.34	4.00	15.02	35.62	14.08	16.78	12.46
140	3.34	0.54	50.54	35.60	35.04	47.56	2.26	35.40	36.62	22.86	21.18
200	1.42	0.22	18.68	35.28	23.50	46.98	–	12.74	26.38	19.50	20.38
270	0.72	–	7.50	19.38	11.00	1.24	–	3.88	10.04	15.40	17.88
Pan	0.76	–	1.96	5.90	2.58	0.04	–	0.76	2.58	14.44	20.08
% of Clay	0.32	–	–	–	0.90	–	–	0.92	1.42	–	–
AFS Fineness	51.4	34.4	111.2	144.4	116.3	118.7	51.7	94.2	117.5	141.7	160.8

RAMMED DENSITY – SAND WITH 2 PER CENT MOISTURE

Table 5 shows the effect on rammed density of adding 2 per cent moisture to the 11 sands under consideration. Here again the relationship of density to GFN follows the general trend of Fig. 2. As might be expected, the densities are consistently lower (2.6-8.0 per cent) than attained by ramming the sands in the dry condition. It should be noted that this technique is considerably different from that reported previously by Heine and Seaton,* and the results are therefore different. By compacting their sand samples in an excess of water they noted a substantial increase in density.

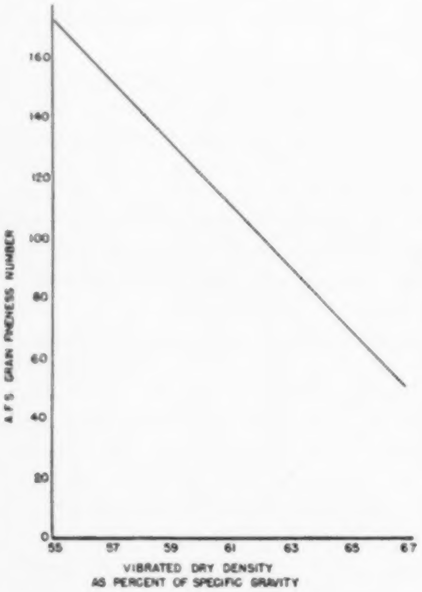

Fig. 2–The trend of relationships of density to GFN.

TABLE 3 – VIBRATED DENSITIES OF DRY SANDS

No.	Name	AFS Fineness No.	Vibrated* Dry Density
1	Muskegon Lake	51.4	66.7
2	No. 60 Silica	34.4	65.4
3	Wedron No. 8	111.2	63.7
4	Wedron No. 10	144.4	63.4
5	Juniata Shell	116.3	62.6
6	Zirconite	118.7	62.2
7	Wedron No. 2	51.7	61.9
8	Vassar Bank	94.2	61.5
9	St. Marie Shell	117.5	60.8
10	Penn Glass	141.7	57.4
11	Manley Silica	160.8	56.2

*Densities expressed as percentages of specific gravity

RAMMED DENSITIES OF BONDED SANDS

For the next series of tests the 11 sands being considered were mixed with 5 per cent western ben-

*R. W. Heine and T. W. Seaton, "Density of Sand Grain Fractions of the AFS Sieve Analysis," MODERN CASTINGS, Feb. 1958, pp. 62-67, and TRANSACTIONS, AFS, *Vol. 66*, 1958, pp. 40-45.

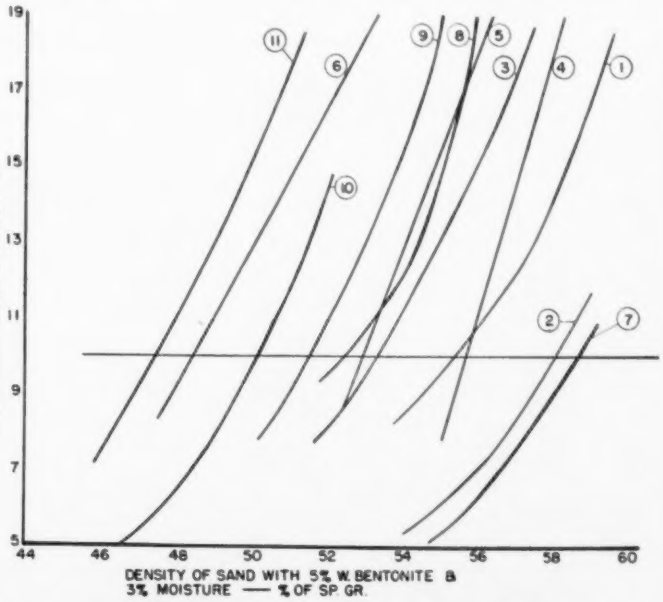

Fig. 3 – Green compressive strength vs. density at different ramming levels.

TABLE 4 – RAMMED DENSITIES OF DRY SANDS

Rams	Densities of 11 Sands Tested										
	1	2	3	4	5	6	7	8	9	10	11
1	61.1	61.1	58.6	58.7	58.9	58.3	61.4	58.3	56.2	52.1	51.3
2	61.9	62.0	59.0	59.2	–	59.0	–	58.6	–	52.6	51.9
3	62.4	62.6	59.4	59.7	–	59.4	–	58.9	–	53.2	52.4
4	62.8	63.1	59.7	60.1	–	59.9	–	59.1	–	53.6	52.8
5	63.2	63.5	60.1	60.5	59.7	60.0	62.8	59.4	57.2	54.0	53.1
10	64.5	64.9	61.9	61.6	60.5	60.8	64.1	60.4	58.4	55.6	54.3
15	65.3	65.5	62.8	62.5	61.4	61.5	64.9	61.1	59.5	56.5	55.1
20	65.5	65.7	63.0	63.1	62.4	62.0	65.3	61.8	60.6	57.5	55.7
Vibrated	66.7	65.4	63.7	63.4	62.6	62.2	61.9	61.5	60.8	57.4	56.2

TABLE 5 – RAMMED DENSITIES OF SANDS WITH 2 PER CENT MOISTURE

Rams	Densities of 11 Sands Tested										
	1	2	3	4	5	6	7	8	9	10	11
1	58.9	57.2	55.5	55.4	55.0	57.8	56.6	54.9	52.8	47.7	47.0
5	59.4	59.0	56.9	57.2	56.9	58.8	58.4	56.7	54.4	49.9	49.2
10	60.5	60.0	58.0	58.2	57.8	59.4	59.7	57.8	55.3	51.4	50.3
15	61.1	60.8	59.1	59.2	58.4	59.9	60.3	58.6	56.0	52.1	51.2
20	61.7	61.6	59.7	59.9	58.9	60.4	60.8	58.9	56.7	52.9	51.9

TABLE 6 – RAMMED DENSITIES OF SANDS WITH 5 PER CENT WESTERN BENTONITE AND 3 PER CENT MOISTURE

Rams	Densities of 11 Sands Tested										
	1	2	3	4	5	6	7	8	9	10	11
1	53.7	54.0	51.6	55.2	52.3	47.5	54.7	51.7	50.1	46.4	45.8
5	56.5	56.2	54.5	56.0	54.5	52.5	56.5	54.3	52.3	48.6	48.6
10	58.0	57.4	55.8	56.7	55.8	54.6	57.6	55.8	53.9	50.4	49.9
15	58.9	58.2	56.6	57.6	56.5	55.3	58.4	56.5	54.9	51.3	50.6
20	59.5	58.9	57.3	58.2	56.9	55.7	59.1	57.0	55.6	52.0	51.3

tonite and 3 per cent water by weight. Table 6 shows the rammed densities. Again, as might be expected, the densities are lower than those of the dry sand or the sand with 2 per cent moisture. The No. 6 sand particularly was affected by the addition of the bond material. Its density was reduced by 7.1 per cent at the 20 ram level.

GREEN PROPERTIES OF BONDED SANDS

The mold hardness, green compressive strength, and permeability were recorded at each ramming level as well as the density. These data are compiled in Table 7. Many efforts to establish definite relationships between these properties and GFN indicated an insufficient data. However, the graphs in Fig. 3, of green compressive strength vs. density at the different ramming levels, indicate the tremendous effect of the raw sand on green strength.

This effect can be attributed to the average grain size, grain-size distribution, grain shape, and surface condition of the sands. In many foundry applications a high green strength, low density sand is ideal. The low density would tend to resist the expansion type of defect. Moreover, the permeability associated with the low density would provide adequate venting.

Figure 4 shows graphs of permeability vs. GFN for two density levels. These graphs depict a relationship

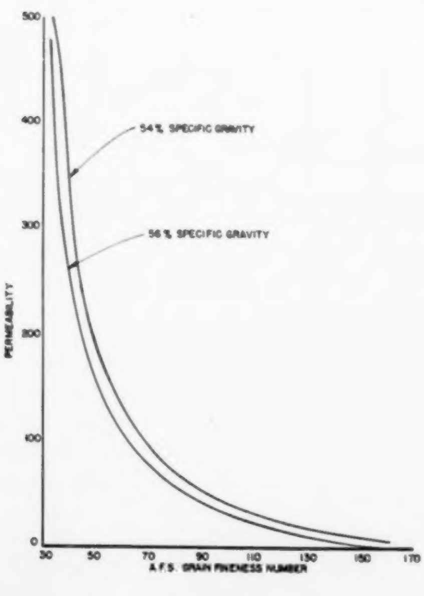

Fig. 4–Permeability vs. GFN for two density levels.

TABLE 7 – PROPERTIES OF SANDS WITH 5 PER CENT WESTERN BENTONITE AND 2 PER CENT MOISTURE

Rams	Density	Hardness	G.S.	Permeability	Density	Hardness	G.S.	Permeability
	Sand No. 1				Sand No. 2			
1	53.7	85	8.2	180	54.0	80	5.3	490
5	56.5	90	11.9	135	56.2	86	7.2	390
10	58.0	92	13.8	115	57.4	89	9.1	340
15	58.9	93	16.6	99	58.2	90	10.2	300
20	59.5	94	18.5	90	58.9	91	11.7	280
	Sand No. 3				Sand No. 4			
1	51.6	86	7.7	55.2	55.2	83	8.2	33.5
5	54.5	90	12.2	35.0	56.0	90	11.4	23.0
10	55.8	92	14.4	29.8	56.7	93	14.7	18.4
15	56.6	92	16.7	26.2	57.6	94	16.9	16.0
20	57.3	93	18.7	23.2	58.2	95	18.7	14.5
	Sand No. 5				Sand No. 6			
1	52.3	89	8.5	45.0	47.5	85	8.3	63.0
5	54.5	92	13.9	34.5	52.5	91	17.6	22.4
10	55.8	93	17.8	28.5	54.6	92	18.7	15.7
15	56.5	94	18.7	26.4	55.3	93	18.7	13.7
20	56.9	94	18.7	24.2	55.7	95	18.7	12.7
	Sand No. 7				Sand No. 8			
1	54.7	80	5.1	200	51.7	84	9.3	63.2
5	56.5	85	6.7	159	54.3	92	12.7	41.0
10	57.6	89	8.7	132	55.8	94	18.7+	33.0
15	58.4	90	10.2	115	56.5	94	18.7+	29.6
20	59.1	91	10.8	107	57.0	95	18.7+	27.6
	Sand No. 9				Sand No. 10			
1	50.1	86	7.8	46.0	46.4	80	4.9	41.0
5	52.3	90	11.7	34.0	48.6	86	7.1	31.6
10	53.9	93	15.3	26.5	50.4	90	10.6	24.0
15	54.9	94	18.7	22.2	51.3	92	12.4	21.8
20	55.6	95	18.7+	21.0	52.0	93	14.7	18.6
	Sand No. 11							
1	45.8	83	7.1	33.0				
5	48.6	90	10.4	22.8				
10	49.9	92	14.9	18.8				
15	50.6	94	16.6	17.0				
20	51.3	95	18.5	14.8				

TABLE 8 – RELATIONSHIP OF PERMEABILITY TO GRAIN FINENESS NUMBER

Name	Sand No.	AFS No.	Avg. Part. Size, mm	Perm. At 54% Sp. Gr.	Perm. At 56% Sp. Gr.
Muskegon Lake	1	51.4	0.30	175	143
No. 60 Silica	2	34.4	0.495	490	396
Wedron No. 8	3	111.2	0.135	37	29
Wedron No. 10	4	144.4	0.105	54	24
Juniata Shell	5	116.3	0.130	35	27
Zirconite	6	118.7	0.125	17	12
Wedron No. 2	7	51.7	0.30	217	169
Vassar Bank	8	94.2	0.16	43	32
St. Marie Shell	9	117.5	0.125	26	19
Penn Glass	10	141.7	0.105	10	3
Manley Silica	11	160.8	0.095	5	0

TABLE 9 – PROPERTIES AT 10 PSI GREEN COMPRESSIVE STRENGTH

No.	AFS No.	Density % Sp. Gr.	No. of Rams	Hardness	Permeability
1	51.4	55.3	3.0	87.8	155
2	34.4	58.1	14.6	90.1	300
3	111.2	53.3	2.7	87.9	45
4	144.4	55.6	2.5	86.5	28
5	116.3	52.9	1.9	89.6	40
6	118.7	48.4	1.4	86	55
7	51.7	58.7	16.8	90.6	110
8	94.2	52.4	1.8	88	58
9	117.5	51.5	3.2	89.4	39
10	141.7	50.1	9.2	89.5	25
11	160.8	47.5	2.5	87.2	27

that is well known, that permeability decreases as the fineness of the sand increases. However, the effect of change in density may be of interest (Table 8).

The overall effects of the raw sand on the green properties of a molding sand are shown in Table 9. The relationships between GFN, hardness, density, and permeability are shown at a green compressive strength of 10 psi. Moreover, the number of rams required to produce this green strength is shown.

CONCLUSIONS

The only conclusions that the author has drawn from this study are:

1. The proper choice of the raw sand for green sand molding is much more important than most foundrymen appreciated.
2. Much more work must be done toward a better understanding of one of the foundry industry's most important raw materials—sand.

THE EFFECT OF VANADIUM ON THE HIGH & LOW TEMPERATURE MECHANICAL PROPERTIES OF A 1Cr-1Mo CAST STEEL

By

L. D. Tote* and R. S. Zeno*

ABSTRACT

A study was made to determine the effect of vanadium content on the high and low temperature mechanical properties of a 1 per cent chromium-1 per cent molybdenum cast steel. The steels were tested in the normalized and tempered condition at comparable hardness levels.

The following effects were observed when step additions of vanadium were made to 10,000 lb heats of 1Cr-1Mo and 1Cr-1Mo-1/4V steels raising the vanadium content from 0.04 to 0.29 per cent, and from 0.23 to 0.54 per cent, respectively.

1. There was a significant increase in the rupture strength at the higher parameter numbers (M = 36,000 to 39,500).

2. Increasing the vanadium from 0.04 per cent to 0.22 per cent lowered the rupture ductility but further increases in the vanadium content from 0.23 per cent to 0.54 per cent did not change the rupture ductility.

3. The tensile and yield strengths appeared unaffected as a result of increasing the vanadium content from 0.23 per cent to 0.54 per cent.

4. Increasing the vanadium content from 0.04 per cent to 0.22 per cent increased the energy and fracture appearance transition temperatures approximately 35 and 19 C, respectively. Increasing the vanadium content from 0.23 per cent to 0.54 per cent showed little, if any, significant change.

5. The bainite became finer with vanadium additions to 0.40 per cent. Bainite coarsening resulted with the 0.54 per cent vanadium content.

6. The grain size increased with vanadium additions to 0.40 per cent. The grain size again became smaller with the 0.54 per cent vanadium.

7. The coarse carbides of iron (Fe_3C) and molybdenum (Mo_2C) are replaced by the finer vanadium carbide (V_4C_3).

8. A nominal 1Cr, 1Mo, 0.5V cast steel has a 1100 F, 100,000 hr rupture strength approaching that of wrought type 347 stainless steel.

9. The 0.1, 0.2 and 0.3 per cent (plastic strain), 100,000-hr creep strength at 1050 F (M = 37,800) approaches that of wrought type 347 stainless steel. At higher parameters the creep strength of the 0.54 per cent V steel appears to fall off.

INTRODUCTION

Low alloy steels in large tonnages are used throughout the world in turbine, oil refineries and other industries where good low and high temperature mechanical properties are essential. For the sake of economy there is a need for developing low alloy steels with high temperature properties (to 1100 F) approaching those of austenitic stainless steels.

It has been recognized for some time that vanadium is one of the most potent high temperature strengtheners of low alloyed ferritic steels.[1,2] In order to explore this further, step additions of vanadium were made to two low alloy ferritic steels. The effect of vanadium content on the high and low temperature mechanical properties of these steels was determined. The results are presented in this paper.

PROCEDURE

Material

Two 10,000 lb heats of steel, one a 1Cr-1Mo (2671), the other a 1Cr-1Mo-1/4V (2759) were made by the basic electric process. The initial vanadium addition to the 1Cr-1Mo-1/4V steel was made in the furnace. The step additions of vanadium were made to both heats in the ladle. The vanadium was added in the form of ferro-vanadium (55 per cent V). The base composition of the two heats, and the vanadium levels of the test blocks poured, are given in Table 1.

Sampling

The test blocks were cast in the form of 1-ft cubes weighing approximately 500 lb. All of the test material was taken from a 1-1/2-in. x 12-in. x 12-in. slab

TABLE 1 – CHEMICAL COMPOSITION OF TEST BLOCKS FROM HEATS 2671 AND 2759

Heat & Test Block	Composition, %								
No.	C	Si	Mn	S	P	Cr	Ni	Mo	V
2671-6	0.18	0.42	0.79	0.007	0.012	0.98	0.15	1.07	0.04 (Base)
2671-9	Base Composition								0.22
2671-10	Base Composition								0.29
2759-1	0.16	0.30	0.83	0.007	0.012	1.12	0.11	0.97	0.23 (Base)
2759-2	Base Composition								0.30
2759-5	Base Composition								0.40
2759-6	Base Composition								0.54

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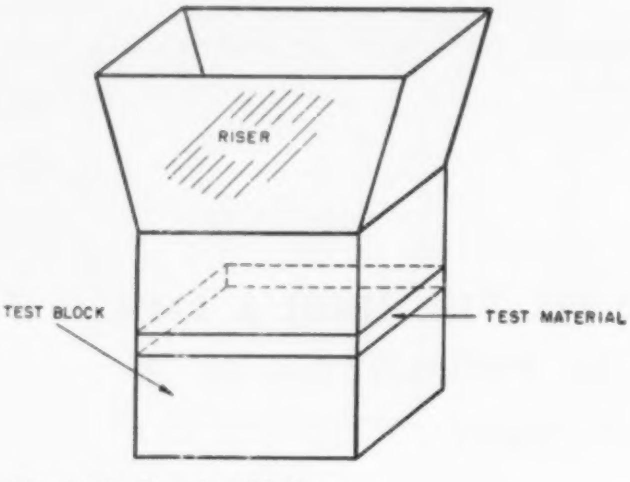

Fig. 1—Sampling of test blocks.

TABLE 2 — SUMMARY OF HEAT TREATMENTS AND RESULTANT HARDNESSES

Identification (%V)	Heat Treatment	Hardness, BHN
2671-6 (0.04)	1030-1075 C (1877-1967 F) for 12 hr 690 C (1274 F) for 10 hr	207
2671-9 (0.22)	1030-1075 C (1877-1967 F) for 12 hr 690 C (1274 F) for 15 hr	217
2671-10 (0.29)	1030-1075 C (1877-1967 F) for 12 hr 690 C (1274 F) for 33 hr	220
2759-1 (0.23)	1050-1080 C (1922-1976 F) for 12 hr 690 C (1274 F) for 41 hr	229
2759-2 (0.30)	1050-1080 C (1922-1976 F) for 12 hr 690 C (1274 F) for 48 hr	230
2759-5 (0.40)	1050-1080 C (1922-1976 F) for 12 hr 690 C (1274 F) for 33 hr 705 C (1301 F) for 30 hr	227
2759-6 (0.54)	1050-1080 C (1922-1976 F) for 12 hr 690 C (1274 F) for 33 hr 705 C (1301 F) for 30 hr	228
2759-6-11 (0.54)	1130 C (2066 F) for 6 hr 690 C (1274 F) for 15 hr	

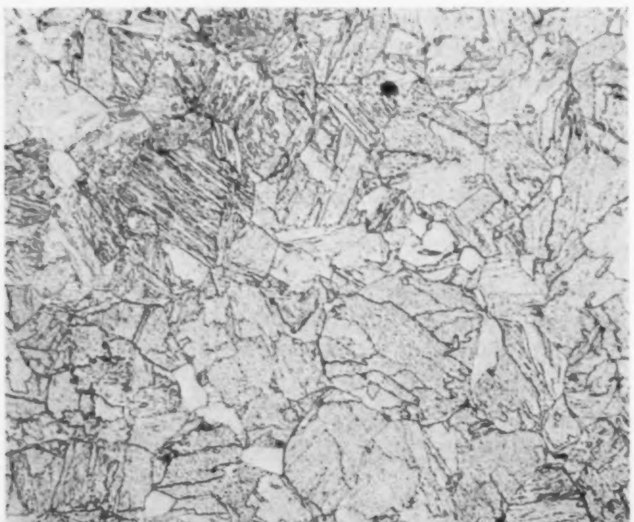

Fig. 2—Test block 2671-6, 0.02 per cent vanadium, bainitic matrix with less than 5 per cent primary ferrite, A.S.T.M. grain size 2-3. 100×.

cut midway between the riser-test-block interface and the test block bottom (Fig. 1).

Heat Treatment

A summary of the normalizing and tempering heat treatments and the resultant hardnesses is given in Table 2. The initial normalizing and tempering cycles were made on the as-cast test blocks. Where additional tempering cycles were required to develop comparable hardness levels, they were run in the laboratory on sections from these test blocks. As the vanadium content in each heat increased, the tempering time required also increased. This retardation of the softening rate according to Zimmerman, et al[3] is caused by the precipitation of the vanadium-rich carbide which has low diffusivity, wide dispersion, and slow coalescence.

Testing

The effect of vanadium content on the microstructure and high and low temperature mechanical properties of a 1Cr-1Mo steel was determined. The tests employed were as follows:

1. Metallographic.
2. Room temperature tensile (Heat 2759 only).
3. V-notch Charpy impact (transition curves).
4. Parameter rupture.
5. Constant load creep (0.54 per cent V material only).

RESULTS AND DISCUSSION

Microstructure

The results of metallographic examinations made on material cut from each of the test blocks investigated are shown and described in Figs. 2-9. At 100× the structures of all but the 0.02 per cent vanadium block (Heat 2671) were bainitic and essentially free of primary ferrite. The 0.02 per cent block showed less

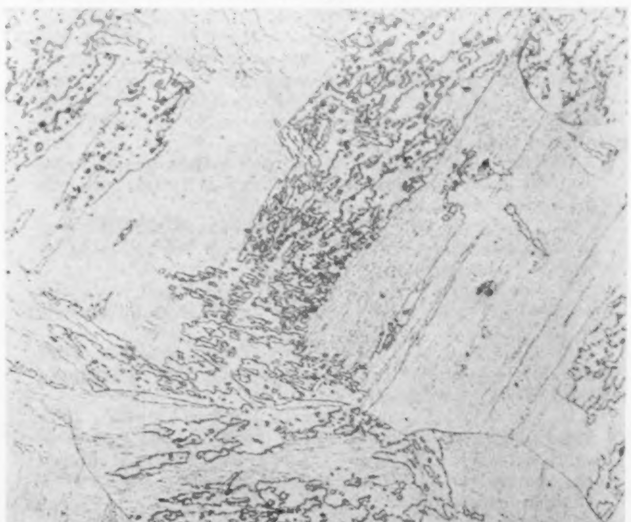

Fig. 3—Test block 2671-9, 0.22 per cent vanadium, coarse bainite free of primary ferrite, A.S.T.M. grain size 1-2. 100×.

than 5 per cent primary ferrite. The bainite in both heats changed with increasing vanadium content.

Increasing the vanadium content of Heat 2671 from 0.02 to 0.29 per cent, and Heat 2759 from 0.22 to 0.40 per cent resulted in the formation of a finer bainite. Increasing the vanadium content of Heat 2759 from 0.40 to 0.54 per cent, however, resulted in bainite coarsening. Strauss & Franklin[4] have found that the effect of vanadium on the type of bainite formed is determined by the undissolved vanadium content as well as the dissolved vanadium content. Vanadium in solution tends to retard the transformation of austenite (increasing ferritic hardenability), whereas undissolved vanadium tends to promote this transformation (decreasing ferritic hardenability).

The grain size of these steels also varied as a function of the vanadium content. The larger grain sizes were obtained with the 0.22 and 0.29 per cent vanadium in Heat 2671, and the 0.40 per cent vanadium in Heat 2759. Increasing the vanadium content of

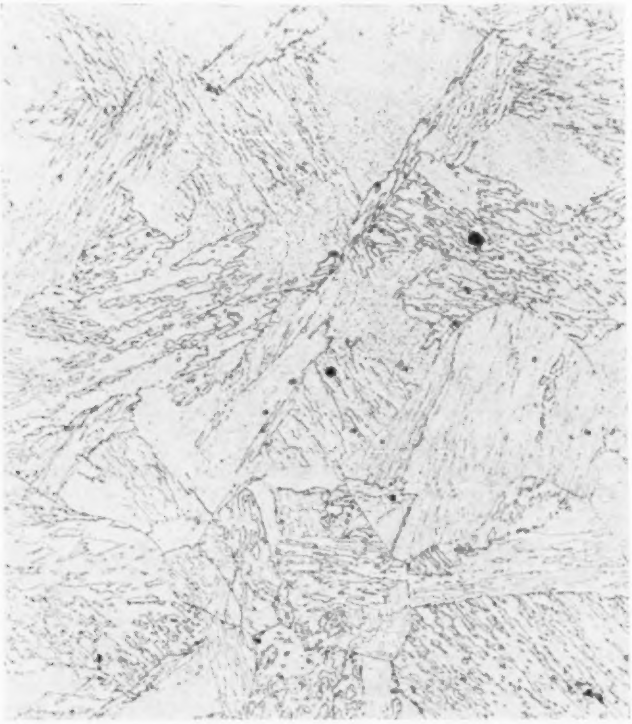

Fig. 4—Test block 2671-10, 0.29 per cent vanadium, bainitic and free of primary ferrite, A.S.T.M. grain size 1-2. 100X.

Fig. 5—Test block 2750-1, 0.23 per cent vanadium, bainite with A.S.T.M. grain size 1-3. 100X.

Fig. 6—Test block 2759-2, 0.30 per cent vanadium, bainite with A.S.T.M. grain size 2-3. 100X.

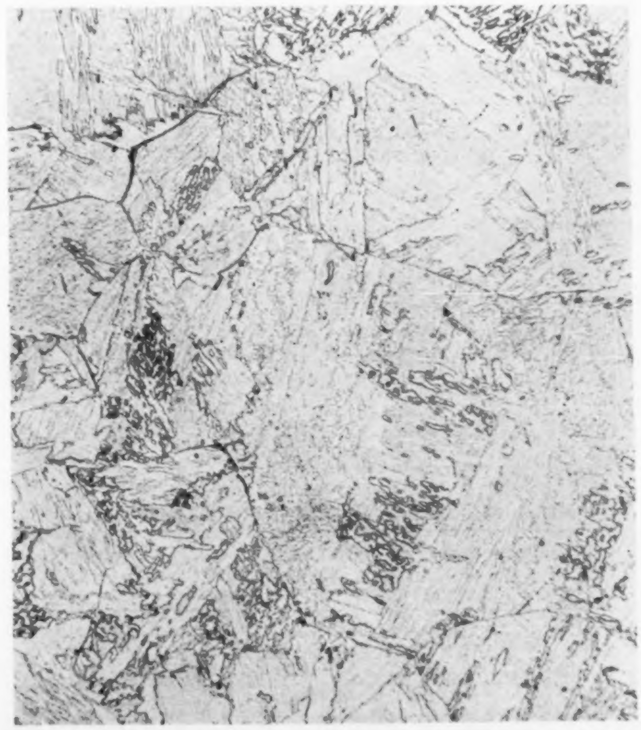

Fig. 7—Test block 2759-5, 0.40 per cent vanadium, bainite with A.S.T.M. grain size 1-2. 100X.

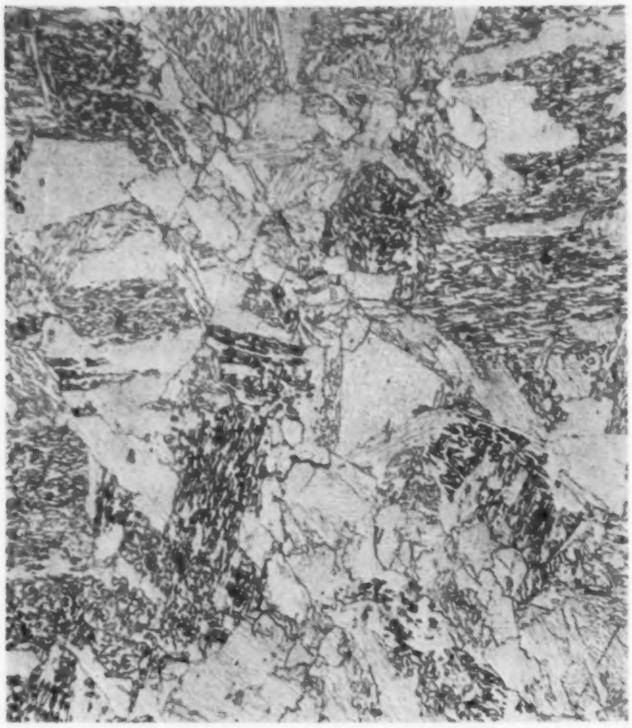

Fig. 8—Test block 2759-6, 0.54 per cent vanadium, bainite with A.S.T.M. grain size 2-4. Austenitized at 1050C (1922F). 100×.

Heat 2759 from 0.40 to 0.54 per cent resulted in the production of a finer grain. It has been reported by Ziegler, et al[5] that undissolved vanadium carbides will restrict grain growth.

It appears from the results of metallographic examination that the maximum vanadium content soluble with an austenitizing treatment of 1050 C (1922 F) for 12 hr is greater than 0.40 per cent, but less than 0.54 per cent.

TABLE 3[6] – X-RAY RESULTS ON STEELS WITH VARYING VANADIUM (7 PER CENT HCL-ALCOHOL ELECTROLYTIC EXTRACTS)

STEEL DESIGNATION	%V IN STEEL	Fe_3C (ORTHORHOMBIC)	Mo_2C (HEXAGONAL)	V_4C_3 (CUBIC)
2759-1	0.23	(a=4.528 Å (b=5.078 Å (c=6.762 Å (a)	a=2.970 Å c=4.678 Å c/a=1.575 (m)	--
2759-2	0.30	(a=4.527 Å (b=5.096 Å (c=6.754 Å (a)	a=2.962 Å c=4.672 Å c/a=1.577 (r)	a=4.194 Å (m)
2759-5	0.40	(a=4.538 Å (b=5.047 Å (c=6.743 Å (a)	a=2.961 Å c=4.671 Å c/a=1.578 (vr)	a=4.190 Å (ma)
2759-6	0.54	(--	--	a=4.183 Å (a)

(a) DESIGNATES "ABUNDANT," (m)"MEDIUM," (r)"RARE," (v)"VERY"

TABLE 4[6] – PARTITIONING OF CR, MO AND V BETWEEN MATRIX AND CARBIDES IN STEELS WITH VARYING VANADIUM

Steel Designation	% V in Steel	Observed Matrix Comp. Cr	Mo	V	Calculated Carbides Comp. Cr	Mo	V	% in Steel	Carbides Type
2759-1	0.23	0.92	0.66	0.13	15	22	7	1.44	Fe_3C+Mo_2C
2759-2	0.30	0.96	0.50	0.12	9	23	9	2.06	$Fe_3C+V_4C_3+Mo_2C$
2759-5	0.40	1.01	0.52	0.20	12	44	20	1.04	$Fe_3C+V_4C_3+Mo_2C$
2759-6	0.54	1.09	0.51	0.15	4	38	31	1.24	V_4C_3

Base Comp. 0.23 V 1.12 Cr 0.97 Mo

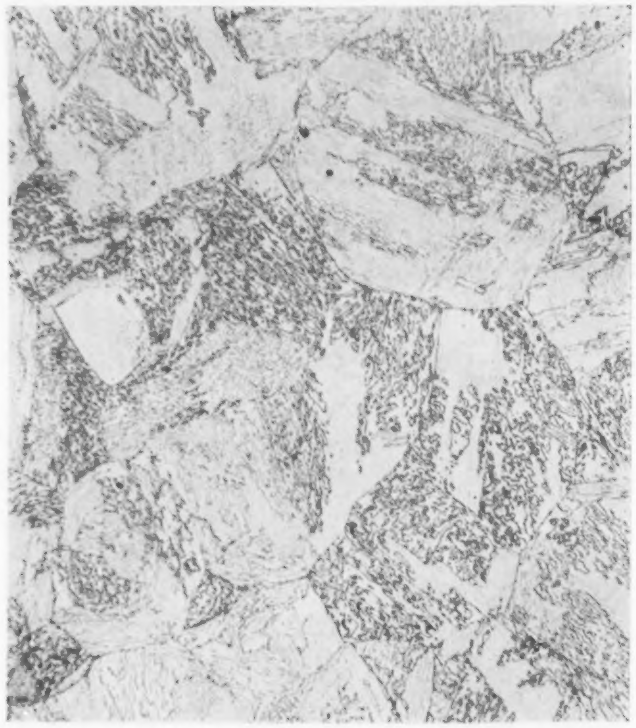

Fig. 9—Test block 2759-6-11, 0.54 per cent vanadium, bainite with A.S.T.M. grain size 1-2. Austenitized at 1130C (2066F). 100×.

At 1000× the carbide spacings appeared larger with increasing vanadium content. What appears to be a depletion in the amount of undissolved carbides is actually a replacement of the coarse iron carbides of iron (Fe_3C) and molybdenum (Mo_2C) with the considerably finer carbide of vanadium (V_4C_3).[6] These vanadium carbides have been resolved at magnifications of the order of 10,000× by Beattie.[6] The results of Beattie's work on the x-ray diffraction of these carbides are summarized in Tables 3 and 4.

TABLE 5 – SUMMARY OF ROOM TEMPERATURE TENSILE RESULTS

Identification (%V)	T.S. psi	Y.S. (0.02% O.S.) psi	Elong. %	R.A. %
1Cr-1Mo* (0-0.05)	88,600	62,600	20.0	56.7
1Cr-1Mo* (0.15-0.20)	101,000	80,500	20.0	55.0
2759-1 (0.23)	104,800	83,000	21.0	63.8
	110,000	88,000	19.5	61.8
	110,000	87,500	20.0	61.8
Ave.	108,270	86,170	20.2	62.5
2759-2 (0.30)	107,200	84,000	20.5	61.6
	106,800	84,000	20.5	61.8
	106,800	84,000	20.5	62.6
Ave.	106,900	84,000	20.5	62.0
2759-5 (0.40)	110,000	85,500	19.5	58.6
	109,000	83,500	20.5	58.1
	109,700	86,250	20.0	58.1
Ave.	109,600	85,100	20.0	58.3
2759-6 (0.54)	112,900	90,000	19.0	54.4
	109,500	88,500	19.0	57.8
	109,000	80,000	20.5	58.6
Ave.	110,500	86,200	19.5	56.9

*Ave. properties based on 10 recent basic electric heats

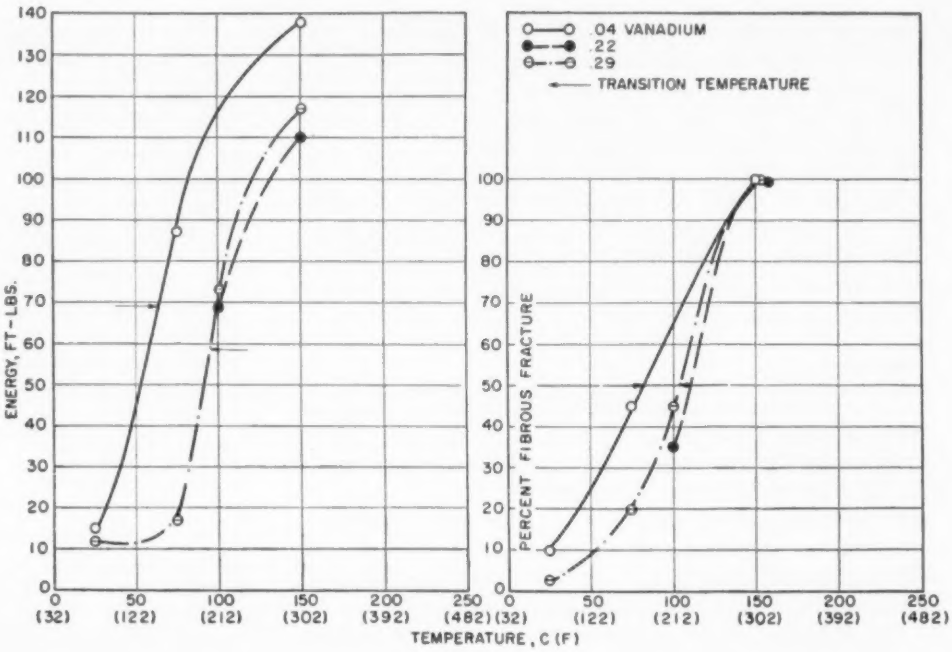

Fig. 10—Energy and fracture appearance transition curves for test blocks from heat 2671.

Room Temperature Tensile

The room temperature tensile properties are summarized in Table 5. When tempered to a strength level of 110,000 psi, the yield strengths remained constant at 85,000 psi. The per cent reduction in area showed a slight decrease with each increase in vanadium content. The decrease from 62.5 to 56.9 per cent is not considered serious.

V-Notch Charpy Impact

The results of the V-notch Charpy tests are summarized in Table 6, and shown in the form of transition curves in Figs. 10 and 11. Fracture appearance transition temperature as a function of vanadium content is shown in Fig. 12. The points plotted for Heat 2671 are the results of single-bar tests at each temperature. The points plotted for Heat 2759 represent the average of two bars. The energy transition temperature was based on 50 per cent of maximum energy.

TABLE 6 – SUMMARY OF V-NOTCH CHARPY RESULTS

Temperature C	0	25	50	75	100	150	250	
F	32	77	122	167	212	302	482	
Identification (%V)								Transition Temp. F
2759-1 Ft-Lb	7	7	18	17	62	109	117	210
(0.23) %F.F.*	0	2	5	10	40	100	100	212
2759-2 Ft-Lb	4	7	11	24	51	83	97	210
(0.30) %F.F.	0	1	4	13	33	98	100	226
2759-5 Ft-Lb	5	6	10	17	38	86	101	230
(0.40) %F.F.	1	3	5	8	25	92	100	242
2759-6 Ft-Lb	3	10	14	29	41	81	86	210
(0.54) %F.F.	1	3	5	13	32	95	100	226
2671-6 Ft-Lb		15		87		138		145
(0.04) %F.F.		10		45		100		180
2671-9 Ft-Lb					69	100		203
(0.22) %F.F.					35	100		215
2671-10 Ft-Lb		12		17	73	117		203
(0.29) %F.F.		3		20	45	100		226

*F.F. – Fibrous Fracture

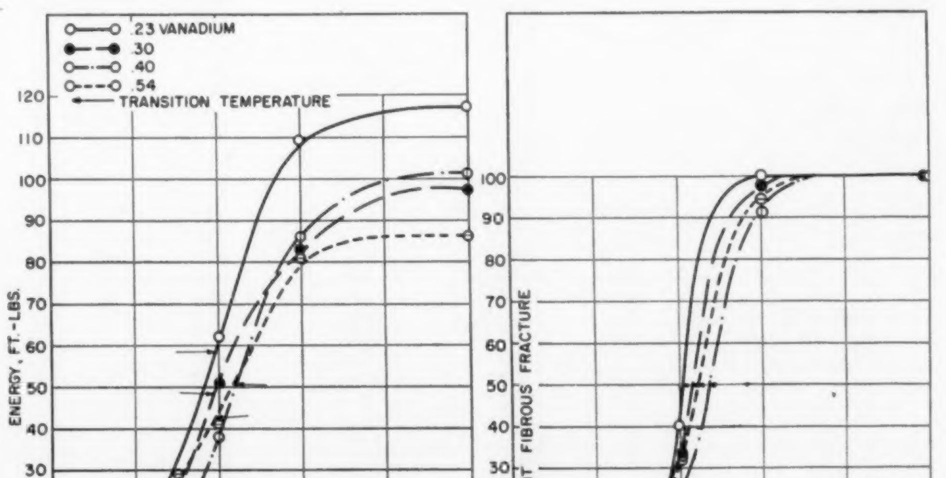

Fig. 11—Energy and fracture appearance transition curves for test blocks from heat 2759.

The fracture appearance transition temperature was based on 50 per cent fibrous fracture.

Increasing the vanadium content of Heat 2671 from 0.04 to 0.22 per cent increased the energy transition temperature from 63 C (145 F) to 98 C (208 F). The fracture appearance transition temperature increased from 82 C (180 F) to 101 C (215 F). Increasing the vanadium content of Heat 2759 from 0.23 to 0.54 per cent showed little, if any, significant change in both the energy and fracture appearance transition temperatures (Fig. 12).

Rupture

The parameter (Larson-Miller[7]) rupture data is summarized in Table 7. The rupture curves for Heats 2671 and 2759 are shown in Figs. 13 and 14, respectively. Figure 15 shows the effect of vanadium content on the 1000, 1050, and 1100 F, 100,000-hr rupture strength of the 1Cr-1Mo steel. Figures 13 and 14 show that in each heat, as the vanadium content increased, the rupture strength increased.

The 0.54 per cent vanadium steel with a 100,000-hr rupture strength at 1100 F of 17,000 psi approaches the rupture strength of wrought type 347 stainless steel (Fig. 15).

The 1000 F rupture ductility of Heat 2671 decreased considerably when the vanadium content was increased from 0.04 to 0.22 per cent (Table 7). The increase from 0.22 to 0.29 per cent vanadium, however, showed little change. In Heat 2759 there was little if any, significant change as a result of increasing the vanadium content from 0.23 to 0.54 per cent. The rupture ductilities were quite low in general.

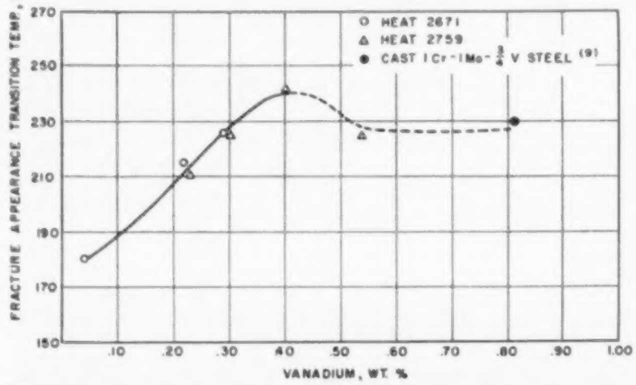

Fig. 12—Fracture appearance transition temperature as a function of vanadium content.

TABLE 7 – SUMMARY OF PARAMETER RUPTURE DATA

Material Heat No.—%V	Hardness BHN	Test Temp. F	Time Hr.	M x 10-3	Stress, psi x 10-3	Elong. %	R.A. %	Type of Fracture	
2671—0.04	207	1200	49	36.0	19	23.0	59	T	I
		1100	160	34.6	28	13.0	34	T	I
		1300	235	39.3	7	22.0	87	T	I
		1050	19	32.1	40	16.0	80	T	I
2671—0.22	217	1300	75	38.4	12	6.0	13	T	I
		1200	172	36.9	19	4.5	9	T	I
		1100	109	34.3	35	9.7	37	T	I
		1000	450	33.0	45	12.0	63	T	I
2671—0.29	220	1300	186	39.1	10	7.4	33	T	I
		1200	162	36.8	23	5.5	10	T	I
		1100	16	33.0	38	12.0	72	T	I
		1100	190	34.7	35	4.3	18	T	I
2759—0.23	229	1300	207	39.2	10	14.0	72	T	I
		1200	871	38.0	23	5.6	17	T	I
		1300	66	38.3	14	3.3	6	T	I
		1200	91	36.4	25	8.5	35	T	I
		1100	86	34.2	38	7.6	39	T	I
2759—0.30	230	1300	284	39.5	10	16.0	71	T	I
		1200	190	36.9	25	5.8	14	T	I
		1100	29	33.4	40	11.0	52	T	I
		1100	193	34.7	36	3.8	19	T	I
		1300	126	38.8	14	7.3	28	T	I
2759—0.40	227	1300	374-437*	39.7-8	10	8.9	45	T	I
		1200	486	37.6	25	8.1	18	T	I
		1100	146	34.5	37	3.3	18	T	I
		1200	163	36.8	28	6.7	22	T	I
		1300	74	38.4	18	4.9	22	T	I
2759—0.54	228	1300	475	39.8	10	10.1	41	T	I
		1300	233	39.3	14	8.4	54	T	I
		1200	159	36.8	30	5.9	32	T	I
		1100	88	34.2	40	7.7	30	T	I
		1300	88	38.6	20	7.8	42	T	I
ICr-IMo-3/4V[9]	237	1300	505	39.9	10	8.0	63	T	I
		1200	504	37.6	22	6.7	27	T	I
		1300	24	37.6	16	18.0	72	T	I
		1100	176	34.7	35	5.9	26	T	I
		1000	13	30.8	47	11.0	64	T	I
		1050	613	34.4	40	4.1	15	T	I
		1300	123	38.8	15	12.0	62	T	I
		1000	976	33.5	40	3.7	6.4	T	I
2759—0.54**	233	1250	626	38.9	15	2.2	17	T	I
		1200	247	37.1	25	2.0	6	T	I
		1100	321	35.1	43	1.4	2	T	I
		1350	76	39.5	11	***	23	T	I
		1200	58	36.1	32	1.9	2	T	I

*Clock broke
**1130C (2066 F) Aust. Treat
***Double neck

It it indicated in the literature by Thielemann[8] and others that with these low alloy ferritic steels, increasing the austenitizing temperature tends to increase the rupture strength and decrease the rupture ductility. Figure 16 shows the comparison of the rupture strength curves of the 0.54 per cent vanadium material austenitized at 1050 C (1922 F) and 1130 C (2066 F). Note the larger grain size of the material austenitized at the higher temperature (Figs. 8 and 9).

Contrary to what has been reported, both the rupture strength and rupture ductility decreased as a result of the increase in austenitizing temperature. One possible explanation for this decrease in rupture strength appears evident. Increasing the austenitizing temperature resulted in a change in the mode of fracture of the material (Table 7). The material austenitized at the lower temperature ruptured in a transcrystalline-intercrystalline manner, whereas, the material austenitized at the higher temperature ruptured along an intercrystalline path. This indicates that in increasing the austenitizing temperature the strength of the grains relative to the grain boundaries has been increased.

The strength of the grain boundaries has decreased to a level below that exhibited by the grains after the 1050 C (1922 F) austenitizing treatment. It appears that the effect of changes in microstructure produced by increasing austenitizing temperatures can and will offset the beneficial effect of vanadium on the rupture strength of these steels. Walker[9] observed the same effect of austenitizing temperature in a study of a 1Cr, 1Mo, 3/4V cast steel.

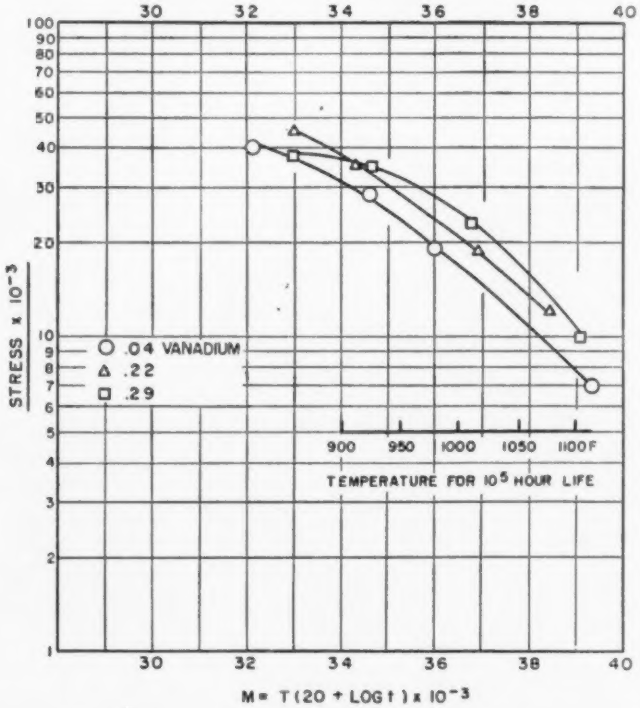

Fig. 13—Rupture curves for test blocks from heat 2671.

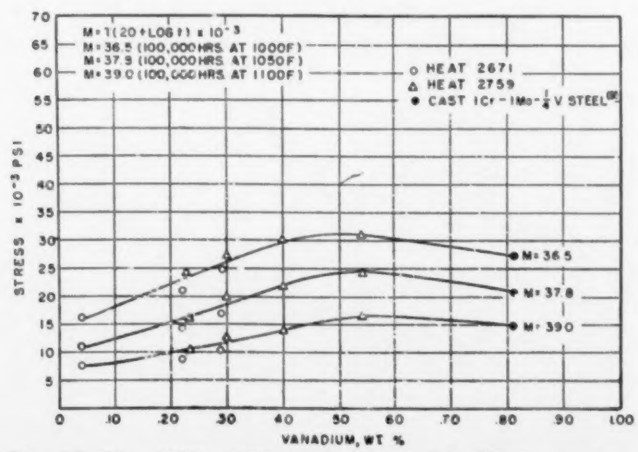

Fig. 15—The 1000, 1050, and 1100F—100,000 hr rupture strength of a 1Cr—1Mo cast steel as a function of vanadium content.

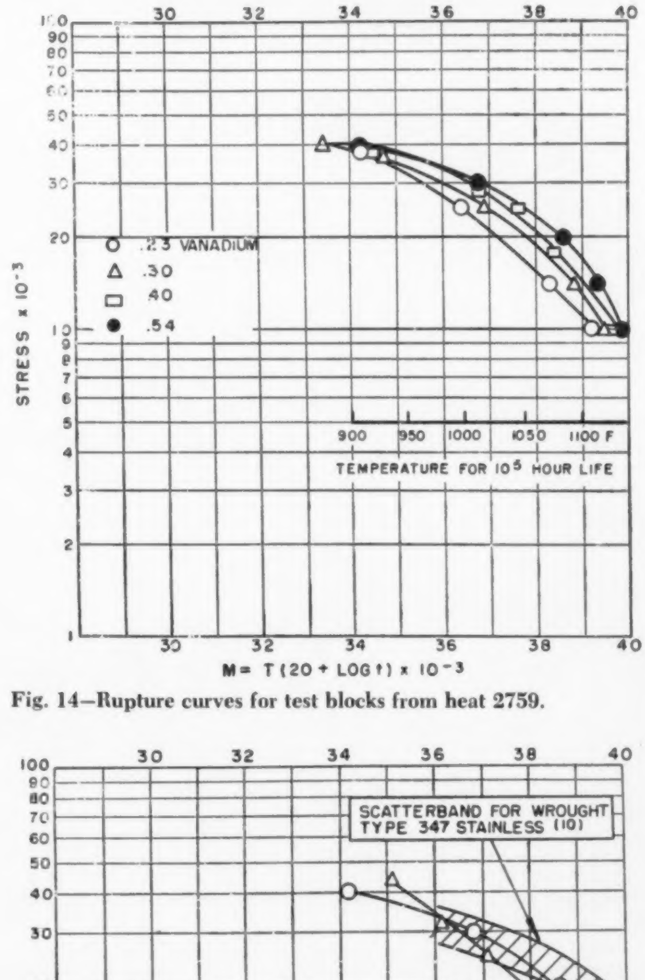

Fig. 14—Rupture curves for test blocks from heat 2759.

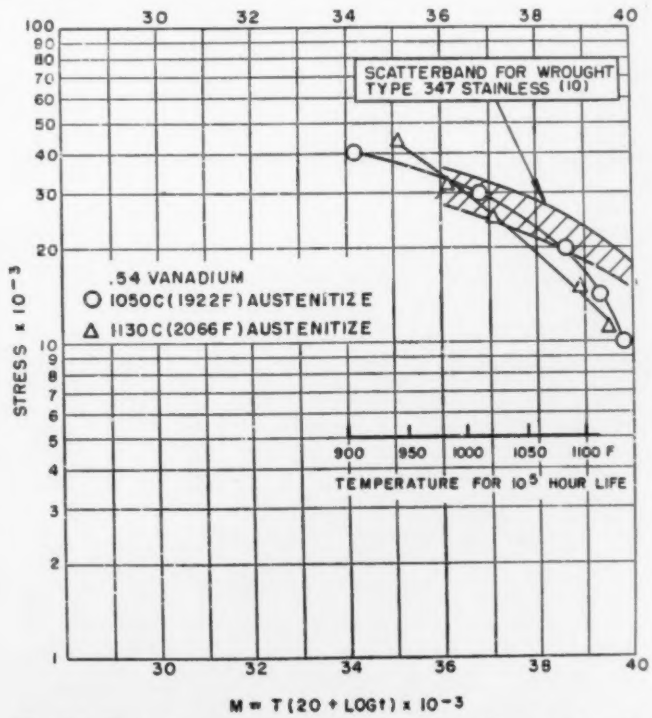

Fig. 16—Rupture curves for 0.54 per cent vanadium steel austenitized at 1050 C (1922 F) and 1130 C (2066 F).

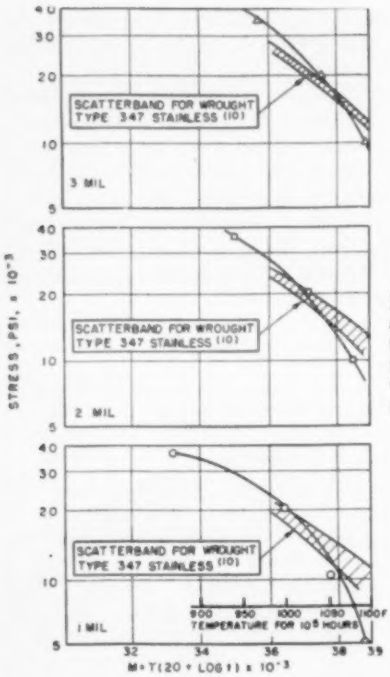

Fig. 17—One, two, and three mil (plastic) creep curves for 0.54 per cent vanadium steel (2759-6).

TABLE 8 – SUMMARY OF PARAMETER CREEP DATA ON 1Cr-1Mo-1/2V CAST STEEL

Heat No. – %V	Hardness BHN	Test Temp. F	Time Hr	M x 10^{-3}	Stress psi, x 10^{-3}	Elong. mils/in.
2759 – 0.54	228	1200	610	37.8	10	0.1
		1200	1600	38.5	10	0.2
		1200	2500	38.8	10	0.3
		1150	475	36.5	20	0.1
		1150	1400	37.2	20	0.2
		1150	2250	37.6	20	0.3
		1250	500	38.8	5	0.1
		1250	1200	39.5	5	0.2
		1250	1780	39.7	5	0.3
		1100	20	33.2	35	0.1
		1100	300	35.0	35	0.2
		1100	820	35.7	35	0.3

Creep

The parameter (Larson-Miller[7]) creep data is summarized in Table 8. The creep stresses required for 1-, 2-, and 3-mil plastic strain for the 0.54 per cent vanadium steel are shown in Fig. 17. Included for comparison is 1-, 2- and 3-mil plastic strain scatterband data for wrought type 347 stainless steel. Note that the 0.1, 0.2, and 0.3 per cent (plastic strain), 100,000 hr creep strength at 1050 F (M = 37,800) approaches that of wrought type 347 stainless steel. At higher parameter numbers the creep strength of the 0.54 per cent V steel rapidly falls off.

CONCLUSIONS

The following effects were observed when step additions of vanadium were made to heats of 1Cr-1Mo (Heat 2671) and 1Cr-1Mo-1/4V (Heat 2759) steels raising the vanadium content from 0.04 to 0.29 per cent, and from 0.23 to 0.54 per cent, respectively.

1. There was a significant increase in the rupture strength at the higher parameter numbers (M = 36,000 to 39,500).
2. Increasing the vanadium from 0.04 to 0.22 per cent lowered the rupture ductility. Further increases in the vanadium content from 0.23 to 0.54 per cent did not change the rupture ductility.
3. The tensile and yield strengths appeared unaffected as a result of increasing the vanadium content from 0.23 to 0.54 per cent.
4. Increasing the vanadium content from 0.04 to 0.22 per cent increased the energy and fracture appearance transition temperatures approximately 35 and 19 C, respectively. Increasing the vanadium content from 0.23 to 0.54 per cent showed little, if any, significant change.
5. The bainite became finer with vanadium additions to 0.40 per cent. Bainite coarsening resulted with the 0.54 per cent vanadium content.
6. The grain size increased with vanadium additions to 0.40 per cent. The grain size again became smaller with the 0.54 per cent vanadium.
7. The coarse carbides of iron (Fe_3C) and molybdenum (Mo_2C) are replaced by the finer vanadium carbide (V_4C_3).
8. A nominal 1Cr, 1Mo, 0.5V cast steel has a 1100 F, 100,000-hr rupture strength approaching that of wrought type 347 stainless steel.
9. The 0.1, 0.2, and 0.3 per cent (plastic strain), 100,000-hr creep strength at 1050 F (M = 37,800) approaches that of wrought type 347 stainless steel. At higher parameters the creep strength of the 0.54 per cent V steel appears to fall off.

When this paper was written, the authors included information and expressed opinions believed to be correct and reliable. Because of the constant advance of technical knowledge, the widely differing conditions of possible specific application, and the possibility of misapplication, any application of the contents of this paper must be at the sole discretion and responsibility of the user.

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Technical Council Outlines Plans for Future Activities

Planning of AFS technical activities for 1958-59 and coordinating of the 63d Castings Congress technical program with the 2d Engineered Castings Show were discussed extensively at the Technical Council meeting held June 6.

Each division will sponsor at least two Congress papers directed toward design engineers and purchasers of castings. In addition two men from each division will comprise a committee to prepare a representative industry-wide castings exhibit for the Show.

The Technical Council, composed of Chairmen and Vice-Chairmen of each of the Society's divisions and general interest committees, also reviewed the tentative 1959 Convention program for approval and suggestions. Technical Council Chairman James S. Vanick presided.

Each division and general interest committee reviewed its 1957-58 program, reported on future plans and made requests for funds necessary to continue its research projects.

Division Reports

Summary of division and committee reports:

Brass & Bronze—Division held two meetings last year. Has 14 papers available for 63d Castings Congress including three on casting design.

Gray Iron—Has 12 active committees. Soliciting more Convention papers from foundries.

Light Metals—Had largest program in history at 1958 Convention. Has papers available on casting design for 1959 Convention.

Malleable—Most committees have research projects.

Pattern—Division has new officers. Chairman, O. C. Bueg; Vice-Chairman, J. M. Kriener; Secretary, R. L. Olson. New pattern color chart will be published soon in MODERN CASTINGS.

Sand—Division, largest in Society, has three members at large to help Chairman and Vice-Chairman carry out duties. Division is preparing three books.

Steel—Urged cooperation with other technical societies in conducting programs.

Die Casting and Permanent Molding—Preparing bibliography on permanent molding. Promotion campaign being prepared to acquaint die casters with AFS.

Cupola Advisory Committee—Working on tuyere design, particularly water-cooled protruding type.

Technical Council meeting held during June in Chicago. Seated at table: E. A. Welander, F. W. Jacobs, L. J. Pedicini, E. C. Zirzow, A. J. Kiesler, H. W. Ruf, C. W. Gilchrist, C. W. Ray, S. C. Massari, J. S. Vanick, L. H. Durdin, H. W. Lownie, Jr., J. S. Schaum, O. C. Bueg, A. H. Rauch, C. E. Westover, R. J. Keeley, R. B. Fischer, R. P. Dunn, J. P. Holt, J. F. Roth. Standing: D. L. Colwell, D. L. LaVelle, Wm. W. Maloney.

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NEWS and VIEWS

Chapter Officers Visit Headquarters

A study of mutual chapter problems using the work shop method proved highly successful at the 15th Annual Chapter Officers Conference held June 12-13 at the AFS Headquarters in Des Plaines, Ill., and the Hotel Sherman, Chicago.

More than 100 Chapter Chairmen, Program Chairmen and other officers and conferees were provided with individual kits containing pertinent data on the Society. Divided into five groups at the Headquarters, they learned the functions of the various AFS departments. Staff members outlined their department activities and explained how chapters could better utilize the services of the Society.

Thirty minutes were devoted to each session covering membership, technical services, Modern Castings, SH&AP activities and educational programs. The relatively small size of the groups and the informal atmosphere led to extensive discussion of mutual problems with the staff members.

Sessions were held Thursday morning and afternoon at the Central office and an outside buffet luncheon was served. A critique of the day's activities was conducted by AFS President L. H. Durdin. After returning by bus to the Hotel Sherman for the Annual Dinner the men heard a talk on "Backdrop for Survival" by Dr. V. Dewey Annakin, Indiana State College, Terre Haute, Ind.

Friday's program was conducted at the Hotel Sherman starting with a buffet breakfast. T&RI Director S. C. Massari gave an explanation of the Training & Research Institute program. A 4-man panel discussed how chapters can build better programs.

Regional administration meetings were outlined by President Durdin and Chapter officers participated in a visioneering session on the subject of "What should AFS be doing five years from now that it is not doing today?"

AFS General Manager Wm. W. Maloney and Curtis C. Fuller outlined the AFS Buyers Directory scheduled for publication in 1959.

Questions accumulated during the 2-day meeting were answered at the "shakeout" session by President Durdin and Staff members. The program was concluded with a getaway luncheon.

National Directors attending: David W. Boyd, Engineering Castings, Inc., Marshall, Mich.; Richard R. Deas, Jr., Hamilton Foundry & Machine Co., Hamilton, Ohio; Jake Dee, Dee Brass Foundry, Houston, Texas; Wm.

MODERN CASTINGS work shops were handled by **Editor J. H. Schaum** (left) and **Advertising Manager J. M. Eckert.** Displays in background acquainted Chapter Officers with the editorial and advertising activities of the magazine.

AFS Technical Director S. C. Massari outlines the plans and policies of the technical program in the library. Chapter Officers are referring to kits containing pertinent data on all phases of AFS operations. **Merle Hansen** of the technical department takes down questions for discussion.

SH&AP Director H. J. Weber briefed foundrymen on the latest in air pollution legislation and workmens compensation laws, pointing out that assistance is available from the Central Office on matters affecting foundries. **Keith L. Potter,** AFS Staff, acted as secretary for the SH&AP sessions.

Chapters; Staff Discuss Ways of Improving Services to Members

D. Dunn, Oberdorfer Foundries, Inc., Syracuse, N. Y.; Herbert Heaton, Mainland Foundry Co., Ltd., Vancouver, B. C.; Webb L. Kammerer, Midvale Mining & Mfg. Co., St. Louis; Fred J. Pfarr, Lake City Malleable Co., Cleveland; John R. Russo, Russo Foundry Equipment Co., Oakland, Calif.

Banquet speaker Dr. Annakin

More than 100 foundrymen attended the **15th Annual Chapter Officers Conference,** the first held at the National Headquarters in Des Plaines, Ill. Conferrees approved holding the meeting at the Central Office and the work shop method of participating in a study of the Society's activities.

President **L. H. Durdin,** shown in center of table, presided at 2-day meeting. With Durdin are Regional Vice-President **John R. Russo** (left) and AFS Safety, Hygiene and Air Pollution Director **H. J. Weber.** The conference provided an additional opportunity for Regional Vice-Presidents and National Directors to discuss chapter problems with the AFS Staff and Chapter Officers.

Genuine interest is reflected in faces of chapter officers attending a **Modern Castings** session. Shown in the background is AFS General Manager **Wm. W. Maloney** who with President **Durdin,** (center rear) and AFS Vice-President **C. E. Nelson** sat in on each of the five workshops. Questions which were not answered during the group meetings were discussed at a Friday "shakeout" session held at the Hotel Sherman in Chicago.

3d Annual Foundry Instructors Seminar

Vocational Teachers Learn Latest in Foundry Developments

Foundry and patternmaking instructors at high schools and vocational schools learned about the latest foundry developments at the 3d Annual Foundry Instructors Seminar held June 19-21 at Case Institute of Technology, Cleveland.

Attending were 111 school instructors, directors and supervisors from the United States, Canada and Indonesia, the largest number to date.

The 3-day program included teaching aids, discussion of curricula, shop layout, laboratory facilities, casting methods, techniques and applications, in-plant training, career opportunities and a foundry inspection trip.

Workshops were used for the discussion of six major topics selected prior to the Seminar by those attending. Each group was led by practicing foundrymen, sales engineers or teaching specialists. The topics and leaders:

Casting display attracts four vocational instructors. Left to right are **John F. Dix,** Schurz High School, Chicago; **Lloyd M. Frazier,** Chester High Vocational Dept., Chester, Pa.; **Leo J. Gardner,** Birmingham High School, Birmingham, Mich.; and **Leo F. Kubacki,** Libbey High School, Toledo, Ohio.

Plant Layout for Industrial Arts, James J. Schwalm, Federal Foundry Supply Co., Div. Archer-Daniels-Midland Co., Cleveland.

Raw Materials for the School Foundry, Burton L. Bevis, Caterpillar Tractor Co., Peoria, Ill.

Projects and Patterns, Donald C. Hartman, Cove Pattern Works, Cleveland.

Sand Conditioning, Norman J. Stickney, Sand Products Corp., Cleveland.

Cast Metals in the General Shop, Prof. John Wallace, Case Institute of Technology, Cleveland.

Melting Non-Ferrous Metals, Michael Chipka, Gluntz Brass & Aluminum Foundry Co., Cleveland.

Workshops were conducted Thursday evening with reports presented Friday morning.

What the future holds for cast and vocational training was discussed by Dewey Barich, Detroit Institute of Technology, Detroit; John P. Walsh, U. S. Office of Education, Washington, D. C.; and I. H. Dennen, Beardsley & Piper Div., Pettibone Mulliken Co., Chicago.

Barich spoke on *Cast Metals in Industrial Arts and Vocational Education Instruction* covering interests, applications, opportunities and objectives. Walsh in outlining *Technical Training for Tomorrow* pointed out the role of educational institutions in meeting manpower needs and new opportunities ahead. Dennen presented a film, *Education and Our Industry's Survival,* emphasizing the need for creating public interest in the casting industry and training opportunities available.

Promotion of closer relations between secondary schools and local foundry interests through mutual understanding was one of the objectives of the Seminar. AFS General Manager **Wm. W. Maloney** explains AFS activities. Also at speakers table are AFS Vice-President **C. E. Nelson** and Education Division Chairman **Burton L. Bevis** who served as Seminar Co-Chairmen.

Frank Cech, (center) head of patternmaking division, Max S. Hayes Trade School, Cleveland, discusses school projects with **Willard J. McCarthy** (left) Illinois State Normal University, Normal, Ill. and **Jim L. Ewen,** Normal Commercial High School, Normal, Ill.

The importance of research and casting quality were highlighted by Prof. John Wallace, Case Institute, and Clyde A. Sanders, American Colloid Co., Skokie, Ill. Wallace in covering *New Casting Developments* brought out industry's use of new materials and methods and application of new alloys and metals. Sanders presented an illustrated lecture featuring casting losses as associated with human errors.

Crucible Melting and Care was presented by Vaun C. Stocker, Joseph Dixon Crucible Co., in which crucible selections and melting procedures applicable to school training programs was emphasized. *Safety in the School Shop* was explained by H. J. Weber, director, AFS Safety, Hygiene and Air Pollution Control, in which he stressed the importance of safety education, danger points and community responsibility.

AFS Education Division plans and activities were discussed. The AFS Training & Research Institute was explained by R. E. Betterley, T&RI Training Supervisor who covered the training provided by the Institute. AFS General Manager Wm. W. Maloney outlined functions of the Society, technical committees, research, publications, conventions, exhibits and future plans.

A panel discussion was held on *AFS & Education* dealing with national, local and industrial assistance to school programs, available literature, and facilities needed.

Cleve H. Pomeroy, National Malleable & Steel Castings Co., Cleveland, was the featured speaker at the Friday banquet speaking on *Education for Foundrymen.*

The Seminar is sponsored by the Foundry Instructors Seminar Committee of the Education Division, R. A. Oster Chairman. B. L. Bevis, chairman of the Education Division and AFS Vice-President C. E. Nelson served as Seminar Co-Chairmen.

Thanks from Instructor

The following letter appeared in the June 27 issue of the Erie Daily Times. Instructor Jordan's expenses were paid by the AFS Northwestern Pennsylvania Chapter.

I have recently returned from the Foundry Instructors Seminar that was held in Cleveland at the Case Institute of Technology and which was sponsored by the American Foundrymen's Society.

My expenses were underwritten by the Northwestern Chapter of this technical organization and I should like to publicly thank them for the opportunity. This was a very intentive course and the benefits that I have gained will be reflected in my teaching.

I wish to commend the American Foundrymen's Society, especially the Northwestern Chapter, for its progressiveness and unfailing efforts in aiding the foundry instructor in any way possible.

JAMES N. JORDON
Metalworking Instructor
Memorial Junior High School
Erie, Pa.

Seminar drew students from United States, Canada and Indonesia. Indonesian representative **Soekarsono** examines castings with **M. Cauchy,** Hull Technical School, Hull, Quebec, Canada; and **Andrew A. Bottoni,** Milwaukee Vocational and Adult School, Milwaukee.

T&RI Sand Course Places Emphasis on Equipment Use

■ Basic testing methods and equipment for determining sand properties and variables and application of controls were presented at the AFS Training & Research Institute Sand Testing Course conducted June 2-6 at the Harry W. Dietert Co., Detroit.

The course prepared for sand technicians, foremen, supervisors, trainees and sand suppliers consisted of lectures, demonstrations and actual use of testing and control instruments by enrollees. Emphasis was placed on the operation of equipment.

Included in course were sessions on Base Properties, Molding Sand Properties, Hot Properties, Core Sand Testing and Shell Testing Methods.

Among the subjects covered in Base Properties were methods of determining the percentage of clay substance and grain fineness, grain shape, sintering and combustion tests.

Molding Sand Properties consisted of lectures and demonstrations on developing green properties including mixing, moisture and permeability tests, strength and deformation tests, flowability and rammability, density, air set and dry strength and sand control records.

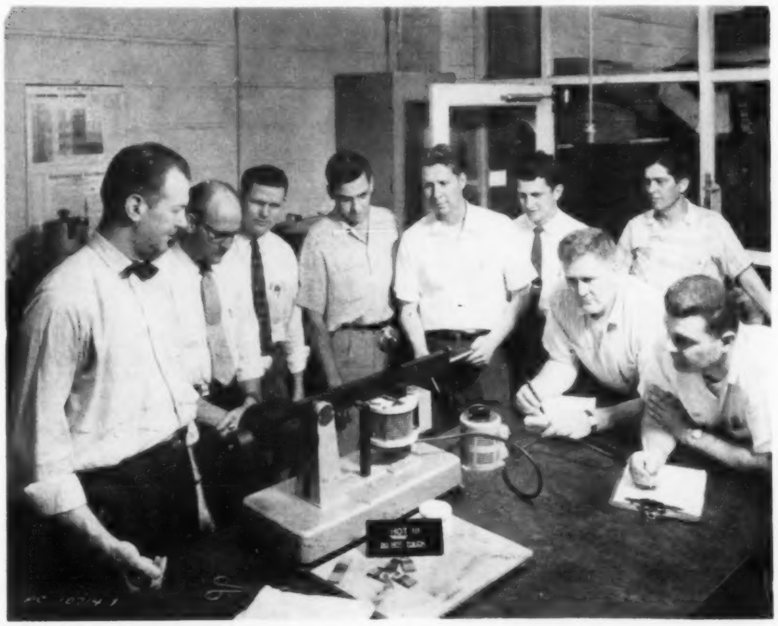
Hot Properties included sessions on hot compressive strength, hot deformation, retained strength, gas evolution test and expansion.

Core Sand Testing included how to prepare a core sand mix, green properties, preparing specimens for baked properties, tensile test, transverse test and bakeability test methods.

Shell Sand Testing Methods involved mixing, curing, strength tests and hot deflection.

A tour was made of the Cadillac Motor Car Division, General Motors Corp. Included were the production line, foundry and assembly plant.

Instructors for the course included Victor M. Rowell, Ray Daksiewicz and Jess Toth of Harry W. Dietert Co., Wayne H. Buell, Aristo Corp., Detroit; and Ted Linabury, National Engineering Co., Chicago.



Demonstration hot-deformation test for shell molds on creep—deformation tester at the H. W. Dietert sand laboratory, Detroit. Left to right: Instructor **Victor Rowell,** H. W. Dietert Co.; **Herbert Cone,** Chambers, Bering, Quinlan Co., Decatur, Ill.; Instructor **Ted Linabury,** National Engineering Co., Chicago; **Richard C. Sheffel,** Bellrose Sand Co., Ottawa, Ill.; **John R. McMahon,** Bucyrus-Erie Co., South Milwaukee, Wis.; **Richard E. Ortengren,** Booty Resineers, Div. American Marietta Co., Newark, Ohio; **Hugh J. Hennessy,** Karbo Bronze Foundries, Inc., Brooklyn, N. Y.; Instructor **Ray Daksiewicz,** H. W. Dietert Co.; **Jay E. Blanke,** M. A. Bell Co., St. Louis.

1951-1957 indexes . . . of MODERN CASTINGS available for each of the seven years. Cross references by subject, author and company pinpoints the issues you need for reference.

1958 T&RI Courses

Sand Control Technology* — **Aug. 11-15—Detroit**
Lecture course for foundrymen having had some experience in sand testing control and technology. Pre-requisite; Sand Testing course or equivalent experience. Registration fee $65.

Patternmaking — **Aug. 18-20—Chicago**
Lecture and demonstration. Course for patternmakers, foremen, supervisors, trainees, purchasers of castings, suppliers and management. Registration fee $40.

Industrial Environment — **Sept. 8-12—Chicago**
Demonstration and lecture course on in-plant environmental problems and safety. Appropriate for foremen, supervisors, engineers, safety men and top management. Registration fee $65.

Metallography of Non-Ferrous Metals* — **Sept. 15-17—Chicago**
Lecture course for melters, supervisors, foremen, foundry engineers, researchers, laboratory technicians, metallurgists and design engineers. Registration fee $40.

Industrial Engineering* — **Sept. 15-19—Milwaukee**
Lecture and work shop course on better standards and cost control. Rating and motions and time study techniques. Registration fee $125.

Product Development — **Sept. 24-26—Chicago**
Lecture course on product analysis from design to marketing of finished castings. Scheduled for foundry engineers, sales engineers, technicians, supervisors, metallurgists and management. Registration fee $40.

Air Pollution Control & Legislation — **Oct. 1-3—Chicago**
Lecture course covering the laws and interpretation, problems, suggested solutions and the drafting of ordinances from the foundry standpoint. Registration fee $40.

Gating & Risering of Ferrous Castings — **Oct. 27-31—Chicago**
Lecture course on the problems relating to gating and risering. Intended for foremen, technicians, foundry engineers, supervisors, industrial engineers and production and quality control personnel. Fee $65.

Foundry Plant Layout — **Nov. 10-12—Chicago**
Lecture course on problems of rehabilitation or building of new plants. Intended for foremen, supervisors, industrial and production engineers and management. Registration fee $40.

Advanced Industrial Engineering* — **Dec. 8-12—Milwaukee**
Work sampling, rating practices, quality control including uses of motion pictures in these phases. Registration fee $125.

*Courses originally scheduled for other dates.

Payment of tuition fees should accompany enrollment application. Make reservations only with Director, AFS Training & Research Institute, Golf & Wolf Roads, Des Plaines, Ill. Tel VAnderbilt 4-0181.

J. H. King Named as New Director

John H. King, president, Archer-Daniels-Midland Co. (Canada), Ltd., Toronto, Ontario, has been appointed as AFS Director replacing Alex W. Pirrie who died in May. King's appointment was unanimously voted by the AFS Board of Directors.

J. H. King

King was born in Toronto and has been associated with Archer-Daniels-Midland Co. since 1939, starting as a salesman and later rising to sales manager, vice-president and becoming president in 1958.

He has presented many talks on practices and principles of coremaking in Canada and the United States. During 1949-50 he served as Chairman of the Ontario Chapter.

Two Represent AFS at 25th International

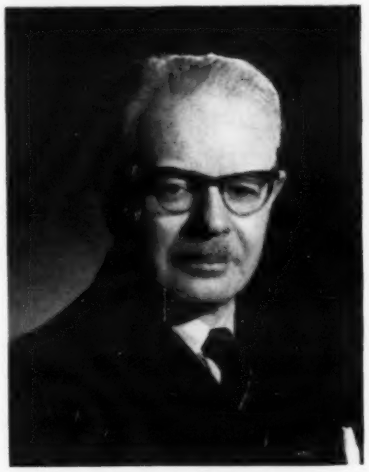
■ AFS Director Richard R. Deas, Jr., Hamilton Foundry & Machine Co., Hamilton, Ohio and AFS European representative Dr. A. B. Everest, Mond Nickel Co. Ltd., London, England, have been named as official AFS representatives to the 25th International Foundry Congress. The Congress will be held Sept. 29-Oct. 3 in Brussels and Liege, Belgium.

Among the sessions to be attended will be the International Committee on Testing Cast Iron, International Committee on Foundry Defects, International Foundry Dictionary Committee and International Committee of Foundry Technical Association.

A. B. Everest Becomes AFS Representative

■ Dr. A. B. Everest, development officer, Mond Nickel Co. Ltd., London, England, has been named as AFS European representative succeeding Vincent Delport who died in June.

After graduation from Birmingham University Dr. Everest obtained his PhD degree for research on aluminum in cast iron and then turned his attention to nickel. For the past 30 years he has been associated with Mond Nickel Co. in the development of alloy and special cast irons and recently with ductile iron.



Dr. A. B. Everest

He has given lectures and technical papers in Europe and the United States and for work for the foundry industry he has received the Oliver Stubbs Gold Medal of the Institute of British Foundrymen and the Gold Medal of the French Foundry Association.

In 1955 Dr. Everest was elected president of the Institute of British Foundrymen and presided over the International Foundry Congress held during 1955 in London. Subsequently he was elected president of the International Committee of the Foundry Technical Associations and in that capacity was International President of the International Congress held during 1957 in Stockholm, Sweden.

AFS Seeks Basic Data by Sponsoring 13 Projects

■ Thirteen research projects are being AFS-sponsored during 1958-59 fiscal year. Six of the projects are being conducted by the Sand Division, one is sponsored jointly with the American Welding Society, one by the Heat Transfer Committee, and one each by the Gray Iron, Brass & Bronze, Light Metals, Malleable and Steel Divisions.

The research projects:

Study of the Theory of Gating and Risering of Gray Iron and Its Practical Application—by Gray Iron Division, at Case Institute of Technology.

Pressure Tightness in 85-5-5-5 Bronze Castings—by Brass & Bronze Division, at University of Michigan.

Thermodynamics of Casting Solidification, by Light Metals Division—project being financed by Ordnance Corps, U.S. Army, at Battelle Memorial Institute.

A Study of Increased Section Size of Malleable Iron Castings Produced Free of Graphitic Carbon — by Malleable Division, at University of Wisconsin.

Physical Properties of Steel Foundry Sands at Elevated Temperatures—by Sand Division, at Locomotive Finished Material Co., Atchison, Kans.

Fundamental Heat Transfer Problems Involved in the Castings Industry—by Heat Transfer Committee, at Columbia University.

Developing Test Standards Applicable to Shell Molding Sands—by Sand Division, Shell Mold & Core Committee.

The Development of Acceptable Welding Techniques for Application on Gray Iron, Nodular and Malleable Iron—by Joint AFS Committee and American Welding Society.

Determination of the Factors Involving Metal Penetration in Mold Surfaces—by Sand Division, Mold Surface Committee.

Segregation in the Handling of Dry Molding Sands—by Sand Division, Grading, Fineness and Distribution Committee.

Correlation between Casting Surface and Hot Properties of Molding Sands—by Sand Division, Physical Properties of Iron Foundry Molding Materials at Elevated Temperatures Committee.

Development of Core Bakeability Tests—by Sand Division, Core Bakeability Test Committee.

Fundamental Study of Cause & Elimination of the Snotter Defect in Steel Castings—by Steel Division.

1959 Apprentice Contest has Earlier Closing Date

■ Apprentices entering the 1959 Robert E. Kennedy Memorial Apprentice Contest are reminded that all entries must be received by March 16, 1959 or three weeks earlier than in 1958.

The earlier closing date results from the 1959 Convention being held during mid-April rather than in May.

No major revisions have been made in the 1959 contest which opens Oct. 1, 1958. Competition will be held in wood patternmaking, metal patternmaking, steel molding, gray iron molding and non-ferrous molding.

National winners will receive $100 for 1st place, $75 for 2d place and $50 for 3rd place. In addition the first two winners in each division will have their round-trip travel expenses paid to and from Chicago.

Eligibility

Any apprentice, learner or trainee in the metalcasting industry who has not had more than five years patternmaking experience, nor more than four years molding experience is eligible to enter.

Membership in the American Foundrymen's Society, either by the contestant or his employing company, is not required. The amount of apprentice training or other training completed has no bearing on eligibility and is not considered in the judging.

Chapter News

Tennessee Chapter Conducts Ladies Night Program

Mueller Corp. employees at **Tennessee Ladies Night:** Mrs. Jack Pope, Mr. and Mrs. Autry Fant, Mr. and Mrs. Edgar Brandt, Mrs. and Mr. John Harp.

Combustion Engineering Co. representatives at **Tennessee** May meeting: Mr. and Mrs. Albert Hicks, Mrs. and Mr. Milton Marks, Mrs. and Mr. Glenn Franklin, Mrs. and Mr. Henry Short.

Crane Co. employees at **Tennessee Ladies Night:** Mr. and Mrs. Al Kitzman, Mr. and Mrs. Frank Jandrlich.

Mrs. Edgar Brandt accepts prize from Chairman Jack Austin at **Tennessee Ladies Night.** —*Carl A. Fischer, Jr.*

Robert J. Mulligan incoming **Twin City** Chairman (right) receives gavel and congratulations from retiring Chairman John Uppgren. Uppgren is foundry manager, Northern Ordnance, Inc., Minneapolis. Mulligan is supervisor of foundry research, Archer-Daniels-Midland Co., Minneapolis.

Twin City Chapters

Features Quality Control

■ Quality control for the small foundry was discussed at the May meeting by J. A. Westover, Westover Corp., Milwaukee. Figures were cited to show that customers place quality ahead of price and service as a factor in purchasing castings. Westover recommended that one person be responsible for all quality control having as his responsibility the checking of new patterns and sample castings and establishing gates and risers for patterns.

Slides were shown demonstrating dimensional, visual, physical, chemical, x-ray and pressure inspection.—*J. David Johnson*

Plant visit to the Philadelphia Coke Co. plant was included in the **Philadelphia Chapter's** educational program conducted annually. The course provided a practical knowledge of sand casting to foundry employees not directly connected with molding or coremaking. It included green sand molding with various types of patterns, coremaking, melting, pouring and handling of metal. Plant visitations, lectures and demonstrations were included. Shown in first row on left are **F. D. Miller** and **H. DeHoll** of Philadelphia Coke Co. On far right is **Ed Saks,** Instructor, Murrell Dobbins Vocational Technical Schools where the classes were conducted. **E. X. Enderlein,** Philadelphia Educational Committee Chairman is shown in the second row, far right—*E. C. Klank, Leo Houser*

Philadelphia Chapter Education Committee Chairman E. X. Enderlein, H. G. Enderlein & Co., Philadelphia, congratulates James E. Gift, Jr., 1st place winner in the steel molding division of the Robert E. Kennedy Memorial Apprentice Contest.—*E. C. Klank, Leo Houser*

Central New York

New Core Processes

■ Various core processes were explained at the May meeting by A. Dorfmueller, Jr., Archer-Daniels-Midland Co. Advantages and disadvantages were covered for shell, air-setting, gas-setting and oil sand cores.

Dorfmueller demonstrated a gas-setting process said to require a setting time of five seconds or less with a tensile strength of 300-500 psi. Several new processes and binders were also described.—*C. W. Diehl*

Anton Dorfmueller, Jr., Archer-Daniels-Midland Co., speaker at the May meeting of the **Central New York Chapter.**

Late arrival at **Central New York Chapter** by Joseph Otvos calls for donation to piggy bank held by Carl Foriero. Leonard Romano, center, apparently arrived on time.

Attending **Central New York** May meeting were Ted Frazell, Bill O'Hora, Al Romeo, Harold Mueller, Chick Jenga and Frank D'Maio.

Toledo Chapter
Gets Students to Show

■ Twenty-eight students in foundry classes at Libbey High School, Toledo, Ohio, had their transportation expenses paid by the Toledo Chapter to and from the 62d Castings Congress & Foundry Show.

A letter of appreciation has been received by the Chapter from J. E. Mohrhardt, Supervisor, Industrial Arts, Toledo Board of Education.

The school foundry equipment includes a 24-in cupola. Students melt 25 tons of iron each school semester from which castings are made for school system.

afs chapter meetings

AUGUST

British Columbia . . Aug. 9 . . Horseshoe Bay, Vancouver, B. C. . . *Annual Salmon Derby, 6:30 am.*

Canton District . . Aug. 2 . . Brookside Country Club, Barberton, Ohio . . *Annual Picnic and Golf Party.*

Twin City . . Aug. 18 . . Midland Hills Country Club . . *Annual Golf Outing.*

Chicago . . Aug. 9 . . Nordic Hills Country Club, Route 53, Itasca, Ill. . . *Annual Golf and Stag Outing.*

Mexico . . Aug. 18 . . Av. Chapultepec 412, Mexico D.F. . . R. Bastida, Aceros Industriales S.A., *"Heat Treatments."*

Ontario . . Aug. 23 . . Hauk Hill Farm, Ont. . . *Annual Picnic.*

St. Louis . August 9 . . Shady Acres, St. Louis County . . *Annual Picnic.*

Southern California . . Aug. 9 . . Lakewood County Club . . *Annual Stag Outing and Golf Tournament.*

SEPTEMBER

Birmingham District . . *No Meeting.*

British Columbia . . .Sept. 19 . . Leon's, Vancouver, B. C. . . R. L. Olson, Dike-O-Seal, Inc., *"Modern Pattern Construction."*

Canton District . . *No Meeting.*

Central Illinois . . Sept. 13 . . Engineers' Club, Groveland, Ill. . . *Fish Fry.*

Central Indiana . . Sept. 6 . . Lake Shore Country Club, Indianapolis . . *Annual Golf Outing and Picnic.*

Central Michigan . . Sept. 17 . . Hart Hotel, Battle Creek, Mich.

Central New York . . Sept. 12 . . Trinkaus Manor, Oriskany, N. Y. . . O. J. Myers, Reichhold Chemicals, Inc., *"Core Binders—Newer Types in New Processes."*

Central Ohio . . Sept. 8 . . Seneca Hotel, Columbus, Ohio.

Chesapeake . . Sept. 26 . . Engineers' Club, Baltimore, Md. . . E. J. Mapes, Pickands Mather & Co., *"Taconite Process," and Film, "Erie Taconite."*

Chicago . . *No Meeting.*

Cincinnati District . . Sept. 8 . . Hotel Alma, Cincinnati.

Connecticut . . Sept. 12 . . Belli's Restaurant, North Wilbraham, Mass. . . *Joint Plant Visitation with New England Chapter, Chapman Valve Co., Indian Orchard, Mass.*

Corn Belt . . *No Meeting.*

Detroit . . *No Meeting.*

Eastern Canada . . *No Meeting.*

Metropolitan . . *No Meeting.*

Mexico . . Sept. 22 . . Av. Chapultepec 412, Mexico City, Mexico . . E. Aleman, Metalurgica Almena S.A., *"Molding Clay & Sands."*

Michiana . . *No Meeting.*

New England . . Sept. 12 . . Belli's Restaurant, North Wilbraham, Mass. . . *Joint Plant Visitation with Connecticut Chapter, Chapman Valve Co., Indian Orchard, Mass.*

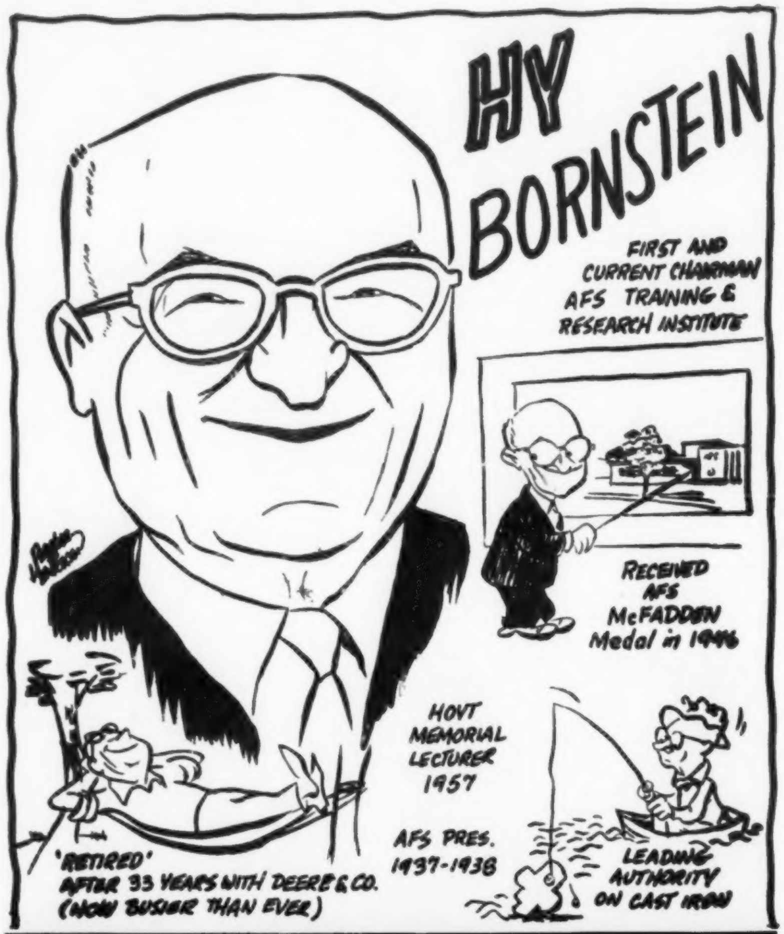
Northeastern Ohio . . Sept. 11 . . Tudor Arms Hotel, Cleveland.

Northern Illinois & Southern Wisconsin . . Sept. 9.

Ontario . . Sept. 12 . . Royal York Hotel, Toronto, Ont. . . *Gray Iron Group:* J. E. Rehder, Canada Iron Foundries, Ltd., *"New Types of Cupolas"; Steel Group:* H. F. Taylor, Massachusetts Institute of Technology, *"Hot Tears in Steel Castings"; Non-Ferrous Group:* H. F. Bishop, Exomet, Inc., *"Manufacture of Pressure Tight Non-Ferrous Castings." Recognition Night for Apprentices and Paper Writing Contestants.*

Philadelphia . . *No Meeting.*

Piedmont . . Sept. 12 . . Hotel Charlotte, Charlotte, N. C. . . C. A. Sanders, American Colloid Co., *"Casting Defects."*



Personalities

Pittsburgh . . Sept. 15 . . Hotel Webster Hall, Pittsburgh, Pa.

Quad City . . Sept. 15 . . LeClaire Hotel, Moline, Ill. . . D. E. Krause, Gray Iron Research Institute, *"Hot Blast Cupola & Slag Control."*

Rochester . . *No Meeting.*

Saginaw Valley . . *No Meeting.*

Southern California . . Sept. 12 . . Rodger Young Auditorium, Los Angeles. . . R. L. Olson, Dike-O-Seal, Inc., *"Modern Pattern Construction."*

Tennessee . . *No Meeting.*

Texas . . Sept. 19 . . Ben Milam Hotel, Houston, Texas.

Timberline . . Sept. 8 . . Oxford Hotel, Denver, Colo.

Toledo . . *No Meeting.*

Tri-State . . Sept. 12 . . Alvin Plaza Hotel, Tulsa, Okla. . . R. L. McIlvaine, National Engineering Co., *"Foundry Layout & Maintenance."*

Twin City . . Sept. 9 . . Jax Cafe, Minneapolis.

Utah . . Sept. 22 . . Salt Lake City.

Washington . . Sept. 18 . . Exeter Hotel, Seattle . . R. L. Olson, Dike-O-Seal, Inc., *"Modern Pattern Construction."*

Western Michigan . . *No Meeting.*

Western New York . . *No Meeting.*

Wisconsin . . Sept. 12 . . Schroeder Hotel, Milwaukee.

Final Report on Castings Congress Technology

■ Following are summaries of technical papers presented at the 62d AFS Castings Congress during Brass and Bronze, Gray Iron, Die Casting, Heat Transfer and Hygiene Sessions held in the Cleveland Auditorium.

Brass and Bronze

Deoxidation Practice for Copper Shell-Molded Castings, R. C. Harris, Frankford Arsenal, Philadelphia.

Because of the nature of the decomposition products of the phenolic resin used in connection with this process, it appears that embrittlement of the castings occurs as a result of the familiar "steam reaction." The reducing gases, generated when the heat of the cast metal decomposes the resin, react with oxides within the melt to form steam, which then causes rupturing at grain boundries.

Conclusions drawn from the results of the work are:

1) As a result of the decomposition of the phenolic resin used in the production of shell molds, a hydrogen-rich atmosphere is generated within the mold cavity which is capable of producing severe embrittlement in copper castings.

2) Of the four deoxidizers investigated (lithium, titanium, phosphorous, and calcium boride) only titanium and lithium effectively deoxidize pure copper for casting into shell molds. The favorable results obtained with titanium and lithium may be due to these elements lowering the oxygen content of the melt to a level where little or no water vapor is generated by the "steam reaction" to cause rupturing at grain boundries.

3) Both gas-fired and high-frequenly (20,000 cps) induction-melting equipment are satisfactory for melting pure copper.

Occurence and Elimination Of Leakage in a Gun Metal Casting, M. Glassenberg, Illinois Institute of Technology; A. H. Hesse, R. Lavin & Sons, Inc., Chicago; and W. H. Baer, Navy Department, Washington, D. C.

1) Employing a runner system in the drag that was progressively throttled down in cross-sectional area to obtain a uniform flow distribution through each gate, castings were produced that did not leak in any part of the machined casting except the outer flange.

The results of high pouring temperature were sporadic. In some cases non-leakers and in other cases, leakers were prevalent.

No definite correlation between x-ray analysis and leakage could be found. Large shrink cracks shown by the x-ray film usually indicated a leaky casting, but a mottled or hazed appearance on the film gave no indication whether the casting would leak or not.

Use of a full, round gun metal chill coated with a graphite wash and placed in the core corresponding to the flange resulted in a sound flange and pressure-tight casting. Ten pressure-tight castings from seven separate heats were obtained by use of chills. Not a single machined casting that used a chill was found to leak.

A joint round table luncheon was sponsored at the 62d Castings Congress by the **Gray and Ductile Iron Divisions.** Presiding were V. A. Crosby, Climax Molybdenum Co., Detroit and W. F. Bohm, Buick Motor Div., GMC, Detroit shown at left. Others are speakers H. A. Laforet, Pontiac Motor Co., Pontiac, Mich., and F. J. Webbere, GMC, Detroit.

Effects of Foundry Variables Upon Porosity of 85-5-5-5 Bronze, R. A. Flinn and C. R. Mielke, University of Michigan, Ann Arbor, Mich.

Pouring temperature, chills and depth testing are variables which affect pressure-tightness readings severely. Moisture content of the mold is less significant in the range tested.

For pressure tightness, castings should be poured at low temperatures and gating adjusted to permit it. Chilling is particularly effectve in removing porosity from critical regions.

The Use of Oil-Bentone Sand for Higher Quality Finish in Brass and Bronze Castings, O. E. Johnson, H. B. Ives Co., New Haven, Conn.

Almost any desired green strength may be obtained by increasing mold hardness and varying the amounts of oil and bentone. Permeability decreases as mold hardness or oil increases; however, permeability is not an important factor with oil-bentone sand.

This sand is easy to use, giving a consistently fine finish and close tolerances. It peels almost completely from the castings, uses far less new sand additions, needs no special equipment and is easy to control. Thinner casting skins result, and metal fills mold cavities more easily because of less chill effect.

The Chemical Treatment of Copper Alloys, R. W. Ruddle, Foundry Services, Inc., Columbus, Ohio.

The main purposes of chemically treating molten non-ferrous alloys are:

1) reduction in melting losses,

2) prevention of dross formation which leads to inclusions in the casting,

3) removal of gases,

4) production of the correct grain structure in the casting.

These results are obtained when precise standard methods are followed. Selection depends upon several factors including the type of melting unit or fuel, the alloy, the form of the charge and the type of casting being made.

Gray Iron

Effect of Size of Scrap on the Tapping Temperature of the Cupola, N. H. Keyser and W. L. Kann, Jr., Battelle Memorial Institute, Columbus, Ohio.

If more coke is added to the cupola charge at the same time that the size of scrap is increased, the additional coke will reach the top of the bed about the same time as the heavy scrap. The added coke will tend to raise the bed and the heavy scrap will tend to lower the bed. Properly selecting the amount of coke will balance out the two effects.

In this study, the required change in rate of charging coke was made in the same charge in which the type of scrap was varied, and the blast rate was maintained constant. By following this technique, the bed height can be maintained at a fixed and predetermined level, and a uniform product can be produced.

A Study of the Ferritization of Nodular Iron, E. J. Eckel, University of Illinois, Urbana, Ill.

Two heat treatments which appear most attractive are:

1) controlled cooling rate through the eutectoid range,

2) isothermal treatment of reheated specimens.

Both treatments are preceded by a high temperature hold. The two treatments gave essentially the same tensile properties, but the first treatment appeared to be capable of producing higher values of impact ductility and had a higher sensitivity to specimen location. The second treatment, while not producing quite as high impact values as the highest reported for the first, gave much less scatter.

The isothermal treatment appears most reliable. However, the fact that the more simple procedure of merely controlling the cooling rate through the eutectoid range gave higher as well as much lower impact values, makes this treatment very interesting. It is quite possible that a detailed investigation might reveal a procedure for elimination of the low values.

The Controlled-Slag Hot-Blast Cupola, D. Fleming, Textile Machinery Makers Ltd., Oldham, England.

A unit has been produced which can be used for acid, neutral or basic melting at will. It is found that some 20 per cent of the total CaO charged is lost, presumably being carried out by the effluent stack gases. Thus all the sources of silica per charge are totalled:

1) silica from metal silicon loss,

2) silica from coke ash (less 2 per cent fly loss),

3) silica from limestone and spar,

4) silica from sand carried in with charges.

The unit will in most cases be used

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REPORT ON . . . . . .

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as a basic melting unit, to enable carbon pick up to be obtained and sulphur removal practised. Especially under European conditions this allows the use of charges compounded of cast iron and/or steel scrap plus ferro-alloys to produce high grade iron from cheap low-grade raw materials.

Under such conditions, the use of hot blast has not only made the requisite metallurgical advantages of low iron oxide content, etc., an assured fact, but has restrained coke consumption to levels similar to cold-blast practice, while giving metal temperatures of a consistently high level, coupled wih lowered silicon losses. Refractory problems, normally so aggravating in the basic cupola have been virtually eliminated.

The unit can be so designed, with due regard to automatic recuperator cleaning, and judicious cooling in metal and slag tap zones, to be capable of 24 hr per day operation for periods up to four weeks duration.

Magnesium Content and Graphite Forms in Cast Iron, J. F. Ellis and C. K. Donoho, American Cast Iron Pipe Co., Birmingham, Ala.

In hyper-eutectic iron increasing magnesium causes a gradual disappearance of graphite flakes in favor of true spherulites. In hypo-eutectic iron increasing magnesium causes the disappearance of true flake graphite in favor of "quasi-flake" graphite form, and then true spherulites.

In very low manganese hypo-eutectic iron, spherulites appear at a much lower magnesium level. Excessive magnesium contents (over 0.14 per cent for the irons studied) cause the appearance of a "spikey" graphite form with some deterioration of properties.

Where spherulites and eutectiform graphite occur together in hypo-eutectic iron, it is shown that the spherulites form first and are contained in the austenite dendrites. A proposed German classification chart for graphite forms associated with spherulitic graphite irons compares reasonably with the various forms observed in this study.

Some Structural Considerations in Nodular Iron, V. Pulsifer, Illinois Institute of Technology, Chicago.

A description of the solidification process of nodular iron is given with the proposal that nodules form near the liquidus in a normal nucleation process rather than near or below

the solidus. This proposal is supported by several observations including studies of rapidly chilled shot.

For all practical purposes, the chemical reaction between magnesium and sulphur is instantaneous, but the separation of the mixed phases is slow. Therefore, more residual magnesium is required with higher sulfur contents to tie up all the sulfur and assure a nodular structure. There is a zone of uncertainty near the stoichiometric ratio where mixed flake-nodular structures occur due to departures from equilibrium in practice.

Gases in Cast Iron with Special Reference to Pickup of Hydrogen in Sand Molds, J. V. Dawson and L. W. L. Smith, British Cast Iron Research Association, Alvechurch, Birmingham, England.

In view of the fact that the hydrogen content of liquid iron can be raised by plunging damp sand into the iron bath, it is not surprising that a similar rise occurs in the sand mold. This hydrogen must come from decomposed water vapor. It would be expected that the presence of easily oxidizable elements in the iron would increase this decomposition.

It is surprising that, whereas aluminum, magnesium and manganese all encourage hydrogen absorption, this pickup is proportional to the magnesium and manganese contents but not to the aluminum content. (There is a little evidence that above 0.1 per cent magnesium this proportionality ceases and the pickup begins to fall again.) This may be due to a tenacious aluminum oxide layer which limits either the reaction with water vapor or the solution of hydrogen.

For the purpose of comparison each conclusion refers first to the pinholing tendency, and second to hydrogen pickup from the mold.

1) Aluminum contents between 0.01 and 0.10 per cent cause pinholing in gray iron and very markedly increases the hydrogen pickup.

2) Aluminum contents over 0.2 per cent reduces pinholing in gray iron and decrease the hydrogen pickup.

3) If titanium is absent aluminum is less likely to cause pinholing in gray iron, but titanium has little effect on the hydrogen pickup either by itself or with aluminum.

4) Magnesium contents up to 0.1 per cent in the absence of aluminum do not cause pinholing, but the hydrogen pickup increases proportionally.

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5) Extremely small amounts of aluminum cause pinholing in presence of 0.04-0.06 per cent magnesium, and also increase hydrogen pickup.

6) When the magnesium content is greater than 0.1 per cent, aluminum is less likely to give pinholing even though the hydrogen pickup is still increased by the aluminum.

Risering of Gray Iron Castings, AFS Gray Iron Division Research Report, J. F. Wallace and E. B. Evans, Case Institute of Technology, Cleveland.

The adequate risering of gray iron castings is a complex problem because of the many variables influencing the melting, casting, and solidification of gray iron in sand molds. It is possible, however, to make several statements concerning good risering practice for general application:

1) A low phosphorous content (below 0.10 per cent) is desirable to eliminate microporosity.

2) Adequate riser size must be selected to compensate for liquid and solidification contraction in all molds. It is also necessary to compensate for some mold cavity enlargement in green sand molds.

3) The mold cavity in dry sand, core, or CO_2 process molds does not expand significantly during solidification of gray iron castings; in fact, a reduction in the mold cavity occurs in heavy sectioned castings in dry sand molds, or when extensive coring is employed. The size of the required risers can be reduced accordingly in these instances.

4) Feeding distance in gray iron is generally greater than that for steel, and it decreases with lower carbon content.

Foundry Applications of the Calcium Carbide Injection Process, W. R. Lysobey and A. E. Tull, Air Reduction Sales Co., New York.

Better cast iron results from good inoculating techniques. An effective inoculant will lower the chill forming tendency of cast iron and promote the formation of Type A graphite in a pearlitic matrix.

The presence of Type D graphite in combination with ferrite is a clue to many of the problems encountered in cast iron founding. This structure is often coupled with white iron or chill formation in adjoining areas which undergo rapid cooling. Many of the difficulties associated with por-

osity and shrinkage can be eliminated or greatly lessened by techniques for producing iron that has Type A graphite and a pearlitic matrix. Injection of calcium carbide in cast iron has this effect.

Duplexing Pays at Pontiac Foundry, H. A. Laforet, Pontiac Motor Co., Pontiac, Mich., and F. J. Webbere, General Motors Corp., Detroit.

Major advantages of duplex melting observed were:

1) improved control,
2) decreased scrap,
3) decrease in cost of charge,
4) increased productivity,
5) cleaner melting operation,
6) reduction in pigged metal,
7) improved relations with machine shop.

Heading the disadvantages of duplexing is the absolute dependence of the entire metal flow on one melting unit. Any shut-down of this unit will stop all the hard iron lines.

Die Casting

Aluminum Melting Practice in the Die Casting and Permanent Mold Fields, J. P. Moehling, Stroman Furnace & Engineering Co., Franklin Park, Ill.

When aluminum is melted in a refractory-lined furnace there is a tendency for an oxide buildup to take place at or slightly above the metal line. This buildup must be removed daily while the refractory lining is hot and must never be allowed to remain while cooling the refractory. Once the refractory has been cooled with this buildup present, there is a definite bond formed between the refractories and the aluminum buildup which causes a more or less permanent deterioration of the refractories and reduces the refractory's ability to resist penetration.

The recent introduction of the vacuum die casting machine makes the growth of aluminum even more certain. This process, while still in the early stages of development as far as aluminum is concerned, opens up new horizons to the die casting technique. The designer has more leeway in integrated, complicated casting designs which formerly required individual castings and subassembly work. The permanent mold and forging field can now be penetrated due to higher physical properties available.

The possibility of casting low sili-

Continued on page 122.

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CO_2 process . . . handbook illustrates equipment and describes process, 46 pp. *Carver Foundry Products Co.*
Circle No. 493, Page 7-8

Conversion factor . . . wall chart reference table for engineers and executives to speed up location of factors used daily. *Precision Equipment Co.*
Circle No. 494, Page 7-8

Temperature conversion . . . chart, wallet-size, available with easy-to-read tables of Fahrenheit and Centigrade temperature equivalents. *Moeller Instrument Co.*
Circle No. 495, Page 7-8

Microscopic photography . . . data book of the elementary photomicrographic technique available in a revised edition. *Eastman Kodak Co.*
Circle No. 496, Page 7-8

Core processes . . . reprint, 6 pp, discusses four major core making processes with a comparison of advantages and disadvantages of each. *Archer-Daniels-Midland Co.*
Circle No. 497, Page 7-8

Welding . . . data book encompasses 120 welding rods, electrodes and welding compounds. *Eutectic Welding Alloys Corp.*
Circle No. 498, Page 7-8

Aircraft castings . . . superior to forgings and fabrications are described in extensive technical report. *General Alloys Co.*
Circle No. 499, Page 7-8

Wood and metal pattern . . . development and production described and illustrated in 12-p booklet. *The Motor Patterns Co.*
Circle No. 500, Page 7-8

Tax guide . . . for small business, 1958 edition. Consists of 128 pp of explanations and answers to most tax problems. *Superintendent of Documents, U.S. Government Printing Office.*
Circle No. 501, Page 7-8

Shell molding . . . silicone parting agents brochure describes how to break-in clean patterns and how to release sand-resin shells and cores. *Dow Corning Corp.*
Circle No. 502, Page 7-8

Water-cooled cupolas . . . technically discussed showing, through modern cupola, purpose of water jackets and high rate of thermal efficiency in cupolas with gradual erosion of lining. *Whiting Corp.*
Circle No. 503, Page 7-8

Stainless steel casting . . . reprint. Describes proper techniques for design engineers. *Cooper Alloy Corp.*
Circle No. 504, Page 7-8

Birth of gray iron castings . . . related in technical, colorful, 20-p book. *Pittsburgh Coke & Chemical Co.*
Circle No. 506, Page 7-8

Radiography . . . in modern industry handbook, 140 pp, well illustrated, for engineer or student. *X-ray Div., Eastman Kodak Co.*
Circle No. 507, Page 7-8

Job evaluation technique . . . in small industry summarized in newsletter. *Small Business Administration.*
Circle No. 508, Page 7-8

Shell cores . . . 4-p reprint, contains diagrams of shell core, mold and finished part. *Cooper Alloy Corp.*
Circle No. 509, Page 7-8

Ceramic gating . . . catalog covers components for all standard cores, splash cores, elbows and tubes. *Universal Clay Products Co.*
Circle No. 510, Page 7-8

Wall chart . . . lists 41 properties for 37 different stainless steels. *Electro Metallurgical Co.*
Circle No. 511, Page 7-8

Ceramic strainer . . . cores and tubes for pouring molten metals are listed on company's specification sheet. *Du-Co Ceramics Co.*
Circle No. 512, Page 7-8

Sand mullers . . . illustrated with specifications in brochure. *National Engineering Co.*
Circle No. 513, Page 7-8

Refractories . . . described with instructions for use and application illustrated in 17-p brochure. *S. Obermayer Co., Ramtite Div.*
Circle No. 514, Page 7-8

Casting resin . . . applications and procedures for patternmaking uses detailed in brochure. *United States Gypsum, Industrial Sales Div.*
Circle No. 515, Page 7-8

Arc torch . . . for fast removal of metal, shown in folder. *Arcair Co.*
Circle No. 516, Page 7-8

Air cylinders . . . and air control valves detailed in brochure. *A. Schrader's Son, Div. Scovill Mfg. Co.*
Circle No. 517, Page 7-8

Blast grit . . . for use in abrasive cleaning is devoid of free silica. Crcle No. 518, Reader Service Card, page 7-8, to request bulletin. *H. B. Reed Co.*

Drum lifter . . . attachments for fork truck or hoist described in brochure. *Ladd Drum Lifter & Equipment Co.*
Circle No. 519, Page 7-8

Sand reclamation . . . process outlined in bulletin. Process removes sand binder coatings. *Guardite Co.*
Circle No. 520, Page 7-8

Welding . . . guide for the foundry presented in illustrated brochure. *Eutectic Welding Alloys Corp.*
Circle No. 521, Page 7-8

Alloying ingredients . . . for production of alloyed steels and irons described and illustrated in booklet. *Alloy Metal Products, Inc.*
Circle No. 522, Page 7-8

Noise reduction . . . graphically portrayed in bulletin. *A.I.C. Engineering Co.*
Circle No. 523, Page 7-8

Ancient bronze . . . castings pictured in booklet. *Sipi Metals Corp.*
Circle No. 524, Page 7-8

Precision instruments . . . for foundry industry listed in catalog. *Illinois Testing Laboratories, Inc.*
Circle No. 525, Page 7-8

Lining and patching . . . cupolas, furnaces, ladles, etc., discussed and equipment illustrated in brochure. *Blastcrete Equipment Co.*
Circle No. 526, Page 7-8

Refractory cement . . . applications, illustrated in technical folder. *Keystone Refractories Co.*
Circle No. 527, Page 7-8

Barrel finishing . . . manual, 48-pp, lists equipment, methods, advantages, uses and supplies. *Almco Div., Queen Stove Works, Inc.*
Circle No. 528, Page 7-8

Degassing agent . . . for aluminum described in brochure. *Foundry Services, Inc.*
Circle No. 529, Page 7-8

Jolt, squeeze, strip . . . molding machine, automatic, described in brochure listing features and molding methods. *Herman Pneumatic Machine Co.*
Circle No. 530, Page 7-8

Attachments . . . for lift trucks, mechanical and hydraulic, listed in 48-p catalog illustrating 26 ways to increase lift-truck use. *Little Giant Products, Inc.*
Circle No. 531, Page 7-8

Flame hardening . . . of castings is discussed in 6-p technical article. *Meehanite Metal Corp.*
Circle No. 532, Page 7-8

Foundry training . . . needs for the present and future are listed and illustrated by graphs in government publication. *Bureau of Apprenticeship and Training, United States Dept. of Labor.*
Circle No. 533, Page 7-8

Grinders and buffers . . . listed with uses shown in catalog. *United States Electrical Tool Co.*
Circle No. 534, Page 7-8

Hand lift . . . trucks comparison chart for evaluation low or high-lift electric trucks of different makes and models. *Lewis-Shepard Products, Inc.*
Circle No. 535, Page 7-8

Mechanical polishing . . . and the effects of pressure during this operation discussed in article. Use Circle No. 536, Reader Service Card, page 7-8, to receive copy. *Beuhler Ltd.*

Compressor . . . new 100 hp model, described and illustrated in bulletin. *Davey Compressor Co.*
Circle No. 537, Page 7-8

High vacuum . . . techniques detailed in colorful 28-p bulletin. Uses include hardening of epoxy resins. *NRC Equipment Corp.*
Circle No. 538, Page 7-8

Facilities . . . and electrical products of plant described in 12-p bulletin. *Crouse-Hinds Co.*
Circle No. 539, Page 7-8

Maintenance . . . equipment for floors and roofs listed and illustrated in literature. *G. H. Tennant Co.*
Circle No. 540, Page 7-8

Temperature control . . . in high frequency induction heating covered in 12-p brochure. *Lepel High Frequency Laboratories, Inc.*
Circle No. 541, Page 7-8

Industrial trucks . . . covered in product review issue of company magazine. *Elwell-Parker Electric Co.*
Circle No. 542, Page 7-8

Level control . . . of bulk, bin material outlined in catalog which includes equipment and systems. *Bin-Dicator Co.*
Circle No. 543, Page 7-8

Stainless steel . . . castings data offered in data sheet covering 29 alloys. *Cooper Alloy Corp.*
Circle No. 544, Page 7-8

Vacuum handling . . . of materials explained and demonstrated in brochure. *Vac-U-Lift Co.*
Circle No. 545, Page 7-8

Overhead storage . . . of clothing and personal effects shown in 8-p booklet. *Moore Co.*
Circle No. 546, Page 7-8

Refractories . . . catalog covers fire brick, cupola block, ladle lining and other refractories. *Robinson Clay Product Co.*
Circle No. 547, Page 7-8

Heat treating . . . equipment, including dimensions and operation, illustrated in 22-p bulletin. *Lindberg Engineering Co.*
Circle No. 548, Page 7-8

Inoculants . . . for cast and ductile iron described in booklets which use pictures, graphs and tables to show advantages. *Electro Metallurgical Co., Div. Union Carbide Corp.*
Circle No. 549, Page 7-8

Colloidal dispersions . . . covered in 12-p booklet which answers many questions about colloids, such as, "What is graphite?" "Why is graphite dispersed in various fluids?" etc. *Acheson Colloids Co.*
Circle No. 550, Page 7-8

Furnaces . . . heat treating and melting, covered in bulletin featuring descriptions, tables and Btu ratings. *Charles A. Hones, Inc.*
Circle No. 551, Page 7-8

Grate magnet . . . for tramp-iron removal described in bulletin. *Stearns Magnetic Products.*
Circle No. 552, Page 7-8

Leasing . . . of materials handling equipment outlined in brochure. *Lewis-Shepard Corp.*
Circle No. 553, Page 7-8

Vacuum cast steel shot . . . for use with company's abrasive cleaning units described in brochure. Reportedly cuts costs. *Pangborn Corp.*
Circle No. 554, Page 7-8

Air compressor . . . operating information for foundrymen presented in 12-p brochure. *Joy Mfg. Co.*
Circle No. 555, Page 7-8

Ventilator . . . which collects fumes and dust at source featured in brochure. *Hawley Mfg. Co.*
Circle No. 556, Page 7-8

Foundry engineering . . . services outlined in brochure. *Lester B. Knight & Associates, Inc.*
Circle No. 557, Page 7-8

Conveyors . . . power belt and gravity type, illustrated in folder. *A. B. Farquhar Div., Oliver Corp.*
Circle No. 558, Page 7-8

Welding equipment . . . automatic and semi-automatic, discussed in folder. *Hobart Brothers Co.*
Circle No. 559, Page 7-8

Hydraulic cylinders . . . bulletin designed to serve as textbook covering use of cylinders. *Miller Fluid Power Div.*
Circle No. 560, Page 7-8

Load handling . . . steel boxes, skids and pallets discussed in 16-p catalog. *Union Metal Mfg. Co.*
Circle No. 561, Page 7-8

Iron powder . . . melting stock, advantages explained in 20-p manual. *Hoeganaes Sponge Iron Corp.*
Circle No. 562, Page 7-8

Laboratory furnace . . . for use up to 4600 F. For literature use Circle No. 563, Reader Service Card, page 7-8. *Zirconium Corp. of America.*

Zinc . . . processes and problems in mining to marketing covered in 96-p booklet. *American Zinc Institute, Inc.*
Circle No. 564, Page 7-8

Conveyor belt . . . literature features specifications and illustrations of foundry uses. *Stephens-Adamson Mfg. Co.*
Circle No. 565, Page 7-8

Hot castings conveyor . . . system described in case history available by circling number below. *Fairfield Engineering Co.*
Circle No. 566, Page 7-8

Nickel supply . . . at present and outlook to 1961 presented in 12-p booklet. *International Nickel Co.*
Circle No. 567, Page 7-8

Radiation safeguards . . . in form of film packets worn by workers involved in handling or proximity to radioactive materials lescribed in 14-p booklet. *E. I. DuPont de Nemours & Co.*
Circle No. 576, Page 7-8

Temperature controls . . . local mounted and remote bulb type, described in 8-p catolog. *Unitel Electric Controls Co.*
Circle No. 577, Page 7-8

free films

■ Motion pictures and other visual aids based on foundry processes and supplies are also yours *for the asking.* These films are suggested for formal or informal training groups. The owners of films in this column will send booking request forms to MODERN CASTINGS readers who circle the appropriate number on the Reader Service card (page 7-8).

Aluminum Welding; Different, Not Difficult . . . color, sound, 16mm. Film shows that aluminum is easy to join by welding, brazing or soldering, using different techniques than those used with other metals. *Reynolds Metals Co.*
Circle No. 568, Page 7-8

Automation Comes to Die-Casting . . . explains completely automatic die-casting machine for small and medium machine parts. 18 min, 16 mm, sound, film. *D.C.M.T. Sales Corp., Div. British Industries Corp.*
Circle No. 569, Page 7-8

17 Films available . . . depicting materials-handling systems in foundries and other industries. Both color and black and white, 16 mm, 29 min. *Clark Equipment Co.*
Circle No. 570, Page 7-8

Hydroperm for Non-Ferrous Castings, . . . 35 mm slidefilm, sound, black and white, 15 min. *United States Gypsum Co.*
Circle No. 571, Page 7-8

Men and Molds, . . . depicts gray iron dry operations in company's plant. Sound, Sound, 16 mm, black and white film, 35 min. *Lynchburg Foundry Co.*
Circle No. 572, Page 7-8

The First Five Minutes, . . . film on industrial fire safety tells of four big responsibilities fire brigade has in first five min of any plant fire. Fire hazards, extinguishers and hoses. *National Board of Fire Underwriters' Film Library.*
Circle No. 573, Page 7-8

How NOT to Conduct a Meeting, . . . film features comedian showing mistakes often made in conducting meetings. 16 mm, sound, 10 min. *General Motors Corp., Public Relations Dept.*
Circle No. 574, Page 7-8

CO_2 Process in the Foundry, . . . shows how the process is applied in the foundry. 16 mm, black and white, sound, 20 min. *Delhi Foundry Sand Co.*
Circle No. 575, Page 7-8

Gating Practice Emphasized in Making Quality Castings

by J. G. Kura
Battelle Memorial Institute
Columbus, Ohio.

A foundry is in business to make a profit by producing acceptable castings. Acceptable castings are those which meet service requirements. Today's increasing demands for maximum serviceability calls for castings of higher quality and on a consistent basis. It is for these reasons that greater attention needs to be given to gating practice.

Research on gating has progressed to the extent that we now have methods to give sound, intelligent direction to the design of an effective gating system. The principles of gating are based on two assumptions: 1) the ladle lip is close to the pouring basin, and 2) the basin is filled quickly and kept full at all times. The objectives of the gating system are:

1) to reduce turbulence in the gating system and in the mold cavity;
2) to reduce the oportunity for dross formation;
3) to eliminate entrainment of air or mold gases by avoiding conditions that would create aspiration;
4) to decrease the velocity of the stream of molten metal and thereby minimize erosion of the mold and cores;
5) to take the "art" out of pouring.

The principles of gating, sometimes referred to as ratio gating, are based on laws of hydraulics, and therefore apply to all metals. The extent to which the principles need to be applied is dependent upon the cleanliness desired in the casting, the design of the casting, and the type of metal being cast. Radiographically clean castings of intricate design, from metals that dross readily, would require careful application of all of the principles. Foundries report results:

1) rejects and reworks reduced from 50 per cent to 8 per cent and yield increased 10 per cent on aluminum cooking utensils;
2) less sand wash, fewer pits, fewer misruns, lower pouring temperature, finer finish and greater yield achieved on brass furniture hardware;
3) cleanliness improved and welding repairs reduced from 8 per cent to 2 per cent on steel grease retainer rings;
4) strainer cores eliminated, dross defects avoided, reduced strains, swells, run-outs and core-wash on iron castings.

let's get personal

T. M. Ware . . . was elected president, International Minerals & Chemicals Corp., Chicago. The former administrative vice-president became the fifth and youngest president of the 50-year-old corporation. He succeeds his father, **Louis Ware,** who was elected chairman of the board and chief executive officer. International is one of the world's largest producers of phosphate and a leader in the mining and processing of potash, feldspar and other industrial minerals.

J. Wesley Lee . . . was elected president and general manager, The Challenge Machinery Co., Grand Haven, Mich. **R. C. Gould** was elected vice-president. Lee succeeds his father, **J. E. Lee,** who died April, 1958, and is the third generation to head the company founded by his grandfather in 1893.

J. W. Swantz . . . was appointed district manager, Wheelabrator Corp., Pittsburgh, Pa., sales office. He replaces **J. F. Underway** who recently resigned to operate his own foundry in South Dakota. **R. F. Morgan** and **R. F. Duff** have also been appointed to the Pittsburgh office. Morgan as sales engineer and Duff as an abrasive engineer.

F. A. Jensen . . . who retired from National Engineering Co., Chicago, has started Foundry Consulting Service, Oswego, Oregon. Jensen is an AFS Chicago Chapter member.

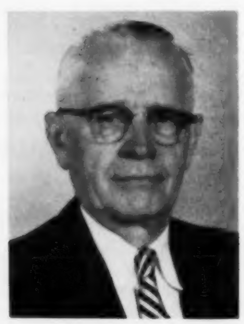
D. S. Grewar . . . recently joined Exomet, Inc., Conneaut, Ohio, in the capacity of sales engineer. He will be located in the Chicago area and has been associated with ferrous and non-ferrous foundry operations for 25 years.

C. L. Benham . . . has retired as district manager, Wheelabrator Corp. Springfield, Mass., sales office but will remain active in an advisory capacity. He has been with the company for 48 years. He is succeeded by **J. H. Burlingame. R. G. Pfliegle** has been appointed the new district sales and service engineer, Burlingame's former position.

Robert Doat . . . Cie General Des Conduites D'Eau. Le Vennes-Liege, Belgium, former vice-president has become president.

R. W. deWeese, . . . vice-president in charge of sales, and **H. T. Swigert** were elected to the board of directors of Electric Steel Foundry Co., Portland, Ore.

D. B. Beath and **L. G. Probst** . . . have been named to fill the newly created posts of Central regional sales manager and Eastern regional sales manager, respectively, of Foundry Services, Inc. Beath was formerly


F. A. Jensen


L. G. Probst


D. B. Beath

with Dewalt, Inc., and Walworth Co. Probst was formerly with National Engineering, Lynchburg Foundry Co. and Bethlehem Steel Co.

C. A. Marlowe . . . has been elected vice-president, Treesdale Laboratories and Textile Processing Co., Mars, Pa. He has been the general manager, Pittsburgh Metals Purifying Co., Mars, Pa., for many years, and will continue in this position in addition to his new office.

C. A. Marlowe

W. P. Cornelius . . . joined the staff of Bernard Johnson & Associates, Houston, Texas. He will assume his new duties in the industrial section of this firm. During World War II he served with the Manhattan District of the U. S. Corps of Engineers. He is a member, AFS Texas Chapter.

F. J. Durzo . . . 44, has been named vice-president in charge of manufacturing by Jeffrey Mfg. Co., Columbus, Ohio. He joined the company as an industrial engineer and two years later became assistant superintendent. In 1953 he was made works manager and four years later was elected to the Board of Directors.

T. L. Hammond . . . has been elected as chairman of the board, Whiting Corp., Harvey, Ill., to fill the vacancy caused by the recent death of his brother S. H. Hammond. He is the son of the late General T. S. Hammond who headed Whiting Corp. until 1950.

F. E. Lutz, . . . Century Brass Works, Inc., Belleville, Ill., has been promoted from general manager to president and general manager.

A. C. Fisher . . . was elected vice-president, in charge of sales and engineering, Pittsburgh Steel Foundry Corp., Glassport, Pa. For the past 30 years, Fisher has been associated with Blaw-Knox Co., Pittsburgh, Pa.,

recently as assistant vice-president of engineering and sales in the Foundry Mill Machinery Division. He has specialized in hot and cold rolling equipment for both ferrous and non-ferrous industries.

Dr. S. T. Jazwinski, . . . director of research, Phoenix Iron & Steel Co., Harrisburg, Pa., received a Doctor of Science degree in metallurgy from Krakow Academy of Mining and Metallurgy.

D. E. Best . . . has been named superintendent of the iron foundry, Bethlehem Steel Co., Bethlehem, Pa., and will continue to be responsible for the brass foundry operations. He succeeds Robert Latham, superintendent since 1939, who retired recently. He is a member of the AFS Philadelphia Chapter and is active in the AFS Brass & Bronze Division.

Dr. A. E. Palty . . . has been appointed supervisor, Alloy Development and Evaluation, Utica Metals Div., Kelsey-Hayes Co., Detroit, producers of vacuum induction melted alloys. Dr. Palty was awarded his doctorate in physical metallurgy in 1954 and is the author of several technical papers on metallurgy.

Circle No. 427, Page 7-8

dietrich's corner

by h. f. dietrich

The Good Job

We have often heard work being described as a good job, or a bad job. I have wondered upon what basis a job can be so classified. Is one pattern better than another? Because a job has lower specifications, and therefore less loss than another, is it a better job than one in which requirements are more rigid? Is a short run less desirable than a job with a long order? What is it that makes a job good or bad?

Just as the depression was ending, I went to Southern Illinois to do some trouble shooting for a small foundry. In spite of having plenty of work, this foundry was on the verge of having their billings placed on 30-day call. Inexperienced help accounted for a scrap percentage slightly above normal for the type of work. But the trouble seemed to be deeper than a lack of skilled help.

Upon examination of the books, I found one company receiving castings from the foundry at prices below market for the work. Because of the finish necessary, the scrap percentage was running a little higher than normal on some items. I met vigorous resistance when I suggested that the prices be raised on this company. I was informed that this was the foundry's best customer, and any raise in price would cause a loss of the business. It was a good job taking 35 per cent of the foundry's tonnage, and there was a chance the tonnage could be increased. Pilot runs had been made on new items—at the same old price per lb. There was little doubt in my mind that the foundry would get the business.

Each job in the foundry should justify its own cost. During a buyer's market, I've seen work taken into a foundry at an average per lb. basis. Perhaps the first group of orders would pay out over-all. But when the time came to rebid on the jobs, those being sold at a loss would be left while those paying the profit would be taken to a lower bidding foundry. Receivership is just around the corner from the foundryman who doesn't know how to correctly figure his costs.

An overenthusiastic sales manager can throw a foundry off stride. This specie of animal is always confident that his foundry can make anything. It's his job to bring work into the shop, and he is forever an optimist. I returned from a vacation one time to find that the sales manager had brought in a truckload of brass gated patterns for short runs. Not one of the patterns was in a hard match. By the time we made match frames, we had more money invested in the work than the total orders returned. From that time on, the sales manager labeled gated work a bad job.

Another sales manager of my acquaintance picked up some patterns of four-in. cross section. Our foundry had built a reputation for finish on gas burners and gas stove grates. If the sales manager had known anything about molding sand and gray iron composition he would have been less enthusiastic about selling castings of four-in. cross section. You can't run 30-ton steam hammer frames in gas burner molding sand. Although it was heavy tonnage and a desirable casting for some foundries, it was a bad job for us.

Most foundries have practically eliminated the loose bench molder. It is their belief that unless you can run long orders a job is not a good job. Pilot and experimental work that produce the high production jobs must still be run from loose patterns before the job can be developed into a high production pattern. To the specialists who handle loose work at a profit, these patterns are good jobs.

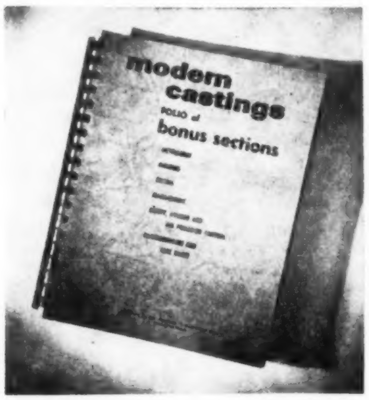
So what makes a good or bad job? If it fits into the foundry line, if it can be run in standard equipment, if it pays a profit, then it is a good job. In other words, any job that can be run at a profit is a good job.

memo

To: Modern Castings Readers

From: the Editor

MODERN CASTINGS entire collection of Bonus Sections published for two and a half years comprising 24 sections of 384 pages has been combined into one attractively covered volume and is being offered at a price of $1.00. Prices for single copies, for groups, and for the total collection are shown.



METALLURGY

Foundry of Tomorrow (24 pp) by Dan L. Smith $0.75
Technology for Casting Titanium (16 pp) by G. H. Schippereit, R. M. Lang, and J. G. Kura 0.50
Special Cupolas & Accessories (12 pp) 0.35
Making Quality Brass and Bronze Castings (12 pp) by R. A. Colton and F. L. Riddell 0.35
Castings Engineered for Industry (28 pp) 0.85
Heat Treating in Malleable Iron Foundries (16 pp) by J. T. Bryce, L. E. Emery, F. W. Jacobs, L. R. Jenkins, G. B. Mannweiler, Wm. Zeunik 0.50
Die Casting (12 pp) by Gustav Lieby 0.35
Complete group of seven Bonus Sections $3.25

MOLDING

Molding Materials, Methods, Machines (16 pp) by R. W. Heine and P. C. Rosenthal $0.50
Molding Machines (8 pp) by J. M. Leaman and D. C. Ekey 0.25
Core Blowing (16 pp) by A. M. Clark 0.50
CO_2 Process (16 pp) by D. V. Atterton, T. E. Barlow, and

Continued on page 118

modern castings

FOUNDRY FACTS NOTEBOOK

TENTATIVE METHOD FOR DETERMANATION OF RESTRAINING LOAD

Foundry Facts Notebook *is designed to bring you practical down-to-earth information about a variety of basic foundry operations. As the name implies, this page is prepared for easy removal and insertion into a notebook for handy future reference.—Editor.*

The restraining load of a sand measures the load in psi that is required to hold a sand test specimen to a constant length when heated to an elevated temperature.

The restraining load test values correlate well with mold wall fracture losses when a test temperature of 1800 F is used.

The restraining load finds a good application to determine the cope scabbing tendency (cope spalling) of a steel molding sand on a scab or no-scab basis. This type of scabbing, or spalling, is due to expansion. So-called scabbing due to erosion, or gas pressure, is due to different mechanisms and cannot be evaluated by this test. The test is made at 1800 F furnace temperature, green hardness as used in foundry, the restraining load is read at 30 seconds ± 1 second tolerance. The average of 10 tests is to be used.

The Committee's findings showed that as a general index a sand with a restraining load in excess of 50 psi, under conditions as specified, will scab in cope. For certain specific steel castings it is well to determine the limit of restraining load value that a sand passes to work free of scab scrap losses.

The restraining load test may be used to measure the scabbing, buckling and rat-tailing tendencies of iron molding sands. When a restraining load test is used to measure iron sands for mold fracture losses as described above, the test conditions are as follows: Furnace temperature, 1800 F; green hardness at value used in the foundry. Read restraining load at 15 second intervals up to 3 minutes and then take readings every 30 seconds up to a total of 5 minutes. Divide the sum of load readings by number of readings taken and record as *restraining load.* Run two such tests and take the average of the two restraining loads as the index of mold wall fracture losses.

The Committee's findings showed that iron sands with an average restraining load of 7 psi or over have scabbing, buckling, and rat-tailing tendencies. The higher the average of the restraining load, the greater the magnitude of these losses.

Physical Properties of Iron Foundry Molding Materials at Elevated Temperatures Committee (8J)

Definition

Restraining load as determined by this test is the load expressed in psi that is required to be placed on a 1-1/8 in. x 2 in. specimen to cause the hot deformation of the sand to absorb the expansion of the sand while length of test specimen is held constant. Time, green hardness and furnace temperature are to be stated with the restraining load.

Equipment Specifications

A dilatometer consisting of a radiant-type furnace capable of operating up to 2500 F, a means for measuring the load, a means of measuring the temperature within the furnace, and controlling the temperature at a predetermined temperature.

An example of a suitable set-up is illustrated.

Preparation of the Test Specimen

The test specimen is to be the AFS Tentative Standard 1-1/8 in. x 2 in. formed in a ground and hardened steel specimen tube.

The sand is to be passed through a 6-mesh screen and sealed in an air-tight container. The test specimens are to be rammed within six hours of the time that foundry molds are made, providing laboratory test data is to be correlated with casting quality.

The test specimens are to be rammed with the AFS Tentative Standard 1-1/8 in. x 2 in. sand rammer, mounted on a concrete or steel pillar or a rammer sub-base.

The specimens are to be rammed to the same hardness to which the sand will be or was rammed in the foundry. When the sand rammer is equipped with an adjustable ramming device, trial and error specimens are rammed until the adjustable ramming device is set to correct height to produce the desired green hardness. In cases where sand rammer is not equipped with adjustable ramming device, one can obtain adjustable weight drop distances by bolting 1/2-in. washers together. Place the assembled washers under rammer weight and suddenly pull washers out to cause weight to fall.

The hardness of the test specimen is measured by stripping the specimen, so that the top of the specimen is flush with the top of the specimen tube. Press hardness tester against top of the specimen.

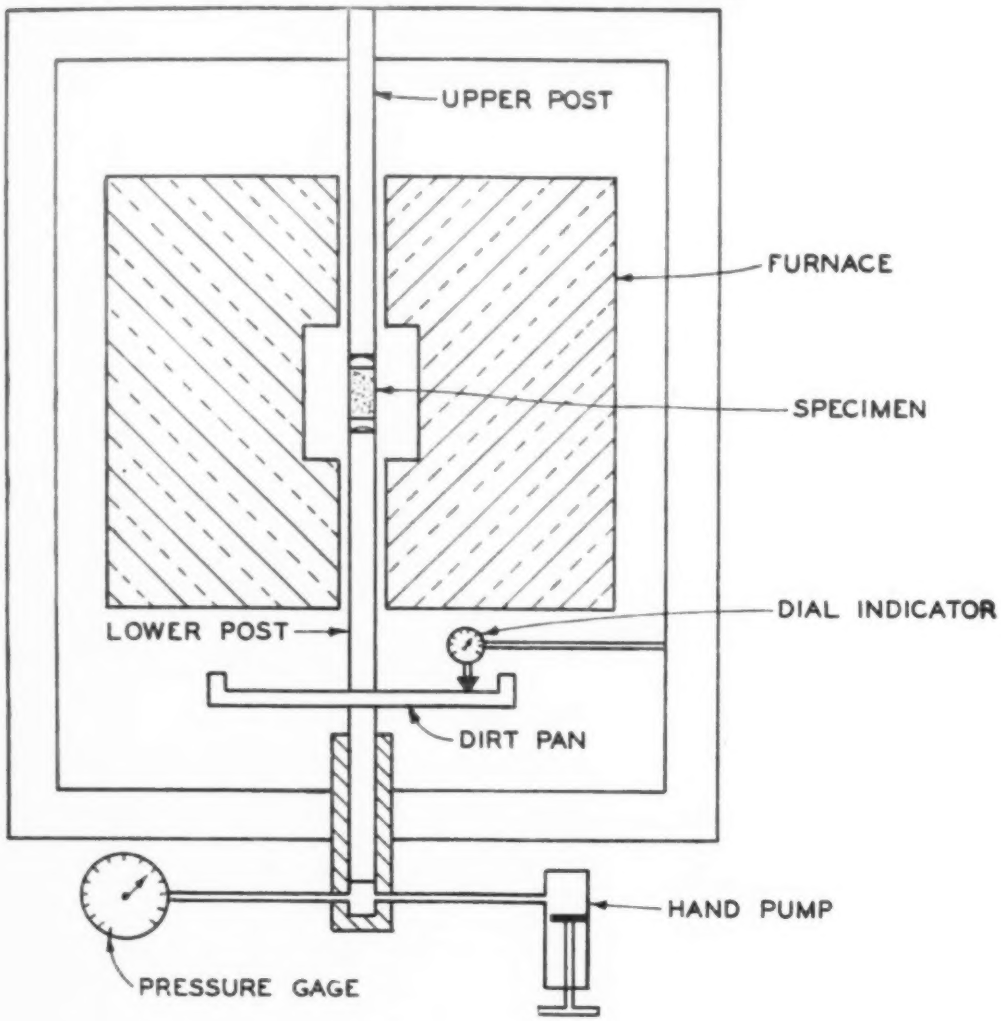
Test Procedure

With furnace and refractory posts in test position, hold at selected temperature for one hour before starting test. Thermocouple for measuring the temperature of the sand specimen should be located at the horizontal centerline of the specimen, not over 3/4-in. from the outside diameter of the specimen.

Ram the test specimen and then place a 1-1/8 in. diameter by 1/2-in. high refractory disc with convex face on top of the specimen. Next, set specimen on a flat refractory disc of same dimensions.

Immediately place the specimen with the discs in the furnace. Cause

Dilatometer arranged for Restraining Load Test.



both refractory posts to make firm contact with the specimen and refractory discs. This is accomplished by applying a 1 psi load. Record dial indicator reading at start, or, if deformation recorder is used to measure the length of the test specimen, rotate recorder drum to indicate pointer position at start. Time for this operation is not to exceed 5 seconds.

Immediately start a stopwatch and apply sufficient load by means of a hand-loading device to cause the length of the test specimen to remain constant within ± 0.001 in. Any change in the length of the test specimen is shown by the dial indicator of the deformation recorder. Adjust load to hold indicator reading constant. Record the load in psi together with time of heating, furnace temperature and green hardness. At end of test remove the specimen and discs.

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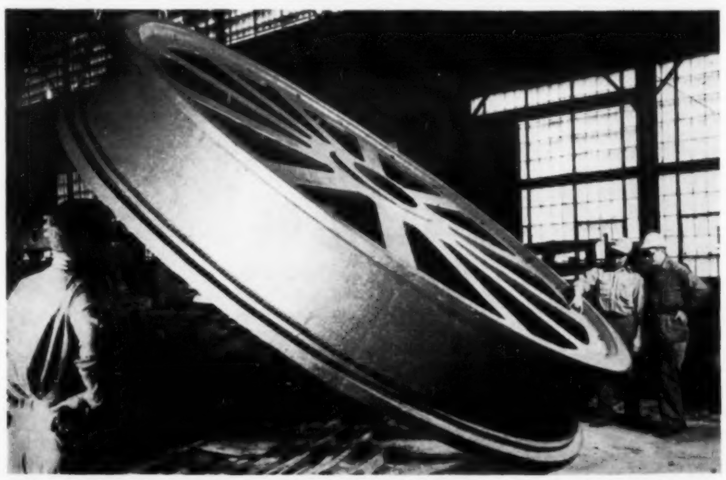
foundry trade news

NATIONAL FOUNDRY ASSOCIATION . . . reports new officers of the National Castings Council are: G. E. Seavoy, Whiting Corp., Harvey, Ill.; R. L. Gilmore, Superior Steel & Malleable Castings Co., Benton Harbor, Mich.; F. R. Fleig, Smith Facing & Supply Co., Cleveland and Frank Steinebach, Penton Publishing Co., Cleveland.

NATIONAL SAFETY COUNCIL . . . figures show foundry injury rates declined in 1957 with the frequency rate (number of disabling injuries per one-million man-hours worked) dropped 11 per cent and the disabling severity fell four per cent. In contrast, the frequency rate for all industry as a whole declined by only two per cent; the severity rate, one per cent.

INVESTMENT CASTING INSTITUTE . . . has completed two new investment casting metal specifications. They are FE-3, for the cast nickel-chromium stainless steel, and CU-2 covering investment casting specifications for beryllium copper. While investment castings are successfully cast to hundreds of alloy specifications, users have found they can expect increased economy and efficiency when they specify to the metallurgical requirements prescribed by the Institute, which are designed as an industry concensus of good practice for both the foundry and the user. ICI specifications are developed by the Institute's Metals Division and are finalized after years of research and consultation with manufacturers and users in the industry.

MAGNESIUM ASSOCIATION . . . elected O. E. Grant president at it's annual meeting held at Grove Park Inn, Asheville, N. C. Grant and other officers will be installed at a luncheon Association meeting during the annual convention Oct. 16-17. in Detroit. Grant succeeds P. B. Craighead, Magnesium Products, Milwaukee. Other officers elected were: N. G. Gzowski, Garfield Alloys, Inc., Cleveland; C. A. Howe, Hills-McCanna Co., Chicago; John Thomson, Dominion Magnesium Ltd., Toronto, Canada. Newly elected directors



This giant steel casting is one of eight sheaves being cast at the Coraopolis, Pa., foundry of Blaw-Knox Co. for the world's longest vertical lift bridge—the Arthur Kill railroad bridge connecting New Jersey and Staten Island. Weighing 60,000 lb unmachined, the casting is over 16 ft in diameter and 31 in. deep. Sheaves will carry 1-1/2-in. diameter wire rope that will raise and lower 558-ft span.

who assume office in October are: Norton Watson, Robert Mitchell Co., Montreal, Can.; A. W. Winston, Dow Chemical Co., Midland, Mich.; D. T. Wellman, Wellman Bronze & Aluminum, Cleveland; Paul Hargitt, Light Metals Inc., Indianapolis; Arley Morse, Modern Light Metals, Coloma, Mich.; J. A. Cosman, Superior Bearing Bronze Co., Woodridge, N. J. and George Kurr, Federated Metals, Div. A. S. & R., New York.

MALLEABLE FOUNDERS' SOCIETY . . . Cleveland, elected R. W. Crannell, Lehigh Foundries Co., Div. Lehigh Inc., Easton, Pa., president at its annual meeting in June. Crannell has served as vice-president, a member of the board of directors and on the market development council of the Society. He succeeds P. C. DeBruyne, Moline Malleable Iron Co., St. Louis. DeBruyne, in his year-end report to members stated the research program has advanced to the point where definite results will be forthcoming, especially in machining characteristics of malleable iron and elevated temperature behavior studies.


J. H. Smith . . . general manager, Central Foundry Div., GMC, Saginaw, Mich., right, receiving the 1958 McCrea Medal in recognition of outstanding service to the malleable iron castings industry. The Malleable Founders' Society's top award is being presented by C. L. Carter, president, Albion Malleable Iron Co., Albion, Mich., at the Society's Annual Banquet in June. Smith is the 12th foundrymen to be so honored since establishment of the award in 1946. He has served as director, president and is now chairman of the Society finance committee. In addition, he is past-president of the Foundry Educational Foundation; regent of General Motors Institute; a past AFS director; and a member, AFS Saginaw Valley Chapter. At the 1953 AFS Convention he was awarded the Peter L. Simpson Gold Medal, and was the 1953 Charles Edgar Hoyt annual lecturer.

GRAY IRON FOUNDERS' SOCIETY . . . recently conducted a series of four regional meetings attended by representatives from over 150 foundries from coast-to-coast. J. S. Parrish, Jr., president, Richmond Foundry &

Mfg. Co., Richmond, Va., and headquarters staff executives were featured speakers at the business sessions held in Monterey, Calif., Waukegan, Ill.; Fort Wayne, Ind. and Pottstown, Pa. President Parrish highlighted the significance of the Society's major programs in his talks and emphasized advantages of foundrymen working together for the over-all good of the industry.

D. H. Workman, executive vice-president, explained how industry's trade association activities have been helping members improve profitable sales.

Quality and Cost Control Through Engineering, was discussed by C. F. Walton, G.I.F.S. technical director and editor of *Gray Iron Castings Handbook*. Walton particularly pointed out the importance of proper utilization of technical personnel in achieving quality and cost controls. At the Pottstown meeting, R. C. Meloy, marketing director, spoke on *Selling More Castings Profitably*. The meetings will be repeated and two more sessions are planned.

I. S. Spencer's Sons, Inc. . . . Guilford, Conn. is commemorating its 100th year of service.

National Metal Abrasive Co. . . . Cleveland, exhibit at the AFS 62d Castings Congress attracted many visitors hoping to win the "guessing contest." Booth had an antique apothecary jar which held 200 lb "T" shot and contest was to guess correct number of shot contained. Many slide rules were in evidence as engineers tried to get the right answer. The prize—the one-millionth General Electric Co. portable television set—was won by Hugh Rudder, foundry superintendent, Massillon Steel Castings Co., Massillon, Ohio, with his estimate of 1,976,471. The official count was 1,984,046 shot but the question most observers asked was how the delicate bottle was filled without being broken.

Hugh Rudder, second from right, admires his prize portable TV won from National Metal Abrasive at AFS 62d Castings Congress. Looking on, left to right, are, Harold Binge, Massilon Steel Castings; Stanley Zansitis, Hickman, Williams & Co.; and D. E. Neustadt, National Metal Abrasive Co.

Photo, courtesy of The Evening Independent, Massilon, Ohio

REPORT ON CASTING TECHNOLOGY

Continued from page 107

con alloys opens up a whole new field for anodized castings which will compete with sheet and extrusions. Competition will become stiffer between stampings and die castings, due to favorable economies of the vacuum die casting technique applied to die casting.

Progress in Vacuum Die Casting, D. Morgenstern, Nelmor Mfg. Corp., Euclid, Ohio.

The use of vacuum in the die casting process has been a major breakthrough in the ability of the die caster to produce better castings at a lower cost. The very nature of the die casting process has within itself the seeds for trouble, due to the fact that when molten metal is injected into dies at high pressures and speed, the possibility of removing entrapped air and gas is limited. The sudden injection of molten metal upon relatively cold dies causes any escape vents for air to be seated by the first flush of metal spraying into the die.

The cold chamber machine, equipped for the vacuum process, presents for the first time a truely universal machine in its ability to run aluminum, zinc and magnesium on the same equipment. Long production runs on zinc parts have been made on a prototype machine, showing comparable speeds on medium and heavy section zinc parts to a hot chamber machine. The hot chamber machine still is needed to produce thin wall zinc sections needing hardware finish.

Die and Permanent Mold Casting of Non-Ferrous Metals in the United Kingdom, L. J. Brice and G. A. Broughton, Ministry of Supply, England.

Standard alloys in current use for die and permanent mold casting are aluminum, magnesium, zinc and copper.

Permanent mold castings have been made to replace the aluminum bronze pulley wheels and the case hardened steel bearing sleeves. Die castings have been produced for small worm wheels and as a replacement of zinc or aluminum alloys for small housings which originally incorporated bronze bushes cast in as inserts.

Experiments have been made in die casting aluminum bronze, but there is no current production since it does not appear to have sufficient advanages over sand castings.

Now that electricity supplies are adequate and are comparatively free from break-down, there is increasing interest in electric heating.

Experiences in Non-Ferrous Die Casting Die & Permanent Mold Life, G. Otto, Maytag Co., Newton Iowa.

The type of die maintenance which is the most repetitive is that due to soldering of aluminum to the steel die. It has been observed that the less the draft on dies, the more severe is the soldering. It is preferable to work with drafts of 3 degrees or more on die casting dies. Dies with this large a draft would last much longer than some dies which have to be built with drafts of one-half degree.

The temperature of the die plays a very important part of the die life. The practice is to attempt to hold an aluminum die casting die at 400 F (204 C). If the die runs hotter, serious soldering is encountered. It is felt that the practice of water spraying contributes a great deal to reduced maintenance costs and improved die life.

Melting Practice for Aluminum Casting Alloys, W. N. Brammer, Apex Smelting Co., Cleveland.

Aluminum alloys have three characteristics which must be guarded against in order to produce good quality castings:

1) the tendency of molten aluminum to absorb hydrogen,

2) the ability of aluminum to oxidize readily,

3) the ease with which molten aluminum dissolves iron.

Cleanliness in the handling and melting of aluminum and positive temperature control are necessary.

Sludging must be avoided. Sludging results when the heavier elements in the alloy, such as Fe, Mn and Cr, are not brought to a temperature hot enough to effect solution.

Overheating has three pronounced detrimental effects:

1) absorption of gas,
2) coarse grain structure,
3) oxidation.

Proper fluxing can effect removal of metallic oxides and foreign material and reduces gas porosity.

Heat Transfer

Relationship of Interface Temperature and Solidification, V. Paschkis and J. W. Hlinka, Columbia University, New York.

The value of the interface temperature between melt and mold has a marked affect on the rate of solidifi-

cation. An investigation was initiated to study the influence of interface temperature only on pure metals (freezing at a constant temperature) rather than for alloys (freezing over a range).

Results are shown for iron, cast in sand or chill and two other molds. Pure iron is not technically significant; yet the results should be of considerable interest because they hold, at least qualitatively, also for steel and are directly indicative of non-ferrous pure metals, such as aluminum.

A generalized chart was developed which allows the determination of the total freezing time for a large slab (no end effects) of any pure material or eutectic alloy cast in a sufficient mold of any material, provided the conductivity of the solid casting is twice that of the liquid. This latter assumption probably holds for many metals.

Ladle Heating in the Foundry, R. B. Renda, Purdue University, W. Lafayette, Ind., and W. M. Zeunik, National Malleable & Steel Castings Co., Indianapolis.

The manner in which the ladles are being heated at the present time (ladle right side up, lid on and closed flame applied at the lip of the ladle) is the most efficient. Explanation for this is that it is possible to maintain a balanced or slightly positive internal pressure in the ladle by this method. Also there is a radiant heat exchange between the red-hot lid and the lining of the ladle.

A comparison of results obtained from three different burners points to one of the aspirator type as the most efficient and economical under the conditions employed. To reach a maximum temperature of 1600 F with a premixing burner required one hr and 30 min heating at a cost of 10 cents.

The aspirator type burner required a heating period of only 35 min to reach a maximum temperature of 1700 F at a cost of only eight cents. With another burner 1-1/2 hr of heating brought the maximum temperature to 1600 F at a cost of 20 cents.

These costs compare with 24 cents for heat lost from molten iron to the lining of an unheated ladle.

Hygiene

Noise Induced Hearing Loss, E. L. Walsh, M. D., International Harvester Co., Chicago.

Deafness due to excessive noise exposure is permanent; the only treatment is prevention. For this reason industrialists are urged to do something about the problem. It will usually cost more not to act than to correct the situation.

The ideal method of control is at the source. Redesign of equipment, substitution of non-vibrating materials for metallic parts, isolation of the process, automation or use of sound-absorbing media may be used.

If engineering and environmental control measurers fail to eliminate the hazard, personal protective measures may be considered. Ear plugs or muffs are helpful. A successful noise hazard elimination program must have primarily the active interest and participation of management.

New Spectrometer Breaks Inspection Time-Barrier

■ Speed is a criterion for aircraft and missiles; it is also the common denominator of competitive techniques for chemical analysis. In the past two years, Modern Castings has featured articles describing: complete chemical analyses in 45 min, 5-min wet analyses and 10-second chemical analyses with x-rays.

But now we have the undisputed winner in this race with the clock—a new device so fast it can complete a chemical analyses in one ten-thousandth of a second! The instrument is an electronic instrument—a mass spectrometer developed by Bendix Aviation Corp.—capable of analyzing an instantaneous sequence of chemical reactions such as take place in the explosion of rocket fuels. It will have numerous applications in the science of missiles ad rocketry as well as aiding in the study of extremely rapid metallurgical reactions.

Returning from "cloud 7" to our own earth-bound metal-casting industry, we find speedy analyses essential in many of our foundries. At Goltra Foundries, Inc., Barrington, Ill., 2-minute carbon analyses are being made by:

1) pouring a furnace sample of plain carbon steel into a water-cooled mold;

2) determining its Rockwell hardness; and

3) reading carbon content from a calibrated carbon vs hardness curve.

Where manpower becomes a problem in plants requiring a large number of analyses, you can benefit from the experiences of Caterpillar Tractor Co., Peoria, Ill.

In their new Metallurgical & Materials Testing Laboratory, using the latest techniques, the number of chemical determinations per man shift are: 17 by wet chemistry; 240 by film-type spectroscope; and 1600 with the direct reading spectroscope!

How long?—5 weeks!

■ Remember, when you change your address, five weeks advance notice is necessary to assure that Modern Castings will be sent to you without interruption. Write to: Circulation Manager, Modern Castings, Golf and Wolf Roads, Des Plaines, Illinois.

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GRAY IRON FOUNDRY SUPERINTENDENT Well-established Chicago gray iron foundry specializing in job-lot production of the highest quality machine tool castings, is seeking a foundry superintendent. Applicant must have a sound knowledge of foundry practice and at least ten to fifteen years' experience in medium and heavy casting work. Practical experience in coremaking, molding, melting and cleaning is necessary. Some technical training is highly desirable. Replies confidential. Send fully detailed resume giving experience, training and salary requirements. **Address Box E-38, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOUNDRY METALLURGICAL ENGINEER Wanted—Foundry Metallurgical Engineer for non-ferrous foundry. Must have experience on problems of gating, risering, pouring, sands and cores. B.S. Degree in Engineering required. Must have minimum of five years experience. Age 25-45. Excellent opportunity for capable and energetic man. Salary open. Please reply stating your personal data, qualifications, experience, salary expected and availability in first letter. All inquiries will be held in strict confidence. **Personnel Department, 1745 South 38th Street, Milwaukee 46, Wisconsin.**

[redacted]

MOLDING MACHINES WANTED One Milwaukee Jolt-Squeeze Stripper Model 216 also one Osborn Roto-Lift Model 3161. **Address Box E-35, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

TRANSACTIONS AFS back volumes and sets—wanted to buy for cash, also other scientific and technical Journals. A.S.F. ASHLEY, 27 E. 21st Street, New York 10, N. Y.

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ELECTRIC ARC FURNACE FOR SALE Two—2000 lb side-charge furnaces complete with transformers, extra tops and electrodes. Low price for quick sale. **FRED H. WUETIG, 7445 South Chicago Ave., Chicago 19, Illinois. HYde Park 8-7470.**

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Chemical Milling Increases Use of Magnesium Thorium

■ It is now possible to successfully apply chemical milling to the middle range, high temperature resistant and mildly radioactive magnesium thorium alloys increasingly specified for aircraft and missile components.

According to the United States Chemical Milling Corp., Manhattan Beach Calif., chemical milling of these alloys, which span the gap in the "strength-temperature" range between conventional aluminum and magnesium alloys, and heavier steel and titanium alloys, eliminate health hazards and simplify machining.

Critical strength temperatures for conventional aluminum and magnesium alloys are in the range of 300-350 F, while those of the new alloys are in the range of 350-500 F.

Health hazards of the low radioactive rates of thorium elements in these alloys are mainly limited to internal radiation from inhaled dusts produced during grinding operations and fumes generated during welding and picking operations. The process is also free of combustion hazards that complicate the physical machining and welding of magnesium-based materials.

In chemical milling, no dusts are produced and fuming is negligible. Disposal of incidental wastes accumulated is accomplished by standard methods.

Company officials state that the sharply increased specification of chemically milled magnesium thorium parts and components in newest missiles and high performance aircraft is evidence that the combination of new techniques developed for the new alloys is having a strong impact on design conceptual thinking.

■ *For additional information on chemical milling, circle A, page 7 and 8.*

At Campbell, Wyant and Cannon—

Quality Control of camshafts starts with

HANNA PIG IRON

Campbell, Wyant and Cannon Foundry Company, division of Textron, Inc., has long been one of the world's leading suppliers of automotive castings. And throughout their many years of pioneering in metallurgy and foundry practice, Campbell, Wyant and Cannon has been a regular user of Hanna pig iron—both standard and silvery.

Typical of C.W.C.'s precision production in volume at their Muskegon, Michigan, foundry are cast camshafts, which were first introduced by C.W.C. to the automotive industry 25 years ago and are now used throughout the world.

Customers' specifications for these camshafts are extremely precise. Dimension, composition, including chemistry and metallurgical structure, hardness—all are vitally important.

In one of the many testing procedures employed to assure that casting quality is up to specifications, C.W.C. through the use of a direct reading spectrometer determines approximately every 20 minutes the analysis of samples taken from electric furnaces and ladles. The commercial application of spectrographic analysis of metals in the foundry was first worked out by C.W.C. in conjunction with the University of Michigan. Only metal made with pig iron of accurate analysis and superior uniformity, like Hanna pig iron, can pass this exacting quality control check.

Hanna produces all regular grades of pig iron as well as HannaTite and Hanna Silvery. All grades are available in the 38-lb. pig and the smaller HannaTen 12½-lb. ingot. Your Hanna representative will be pleased to tell you more about the advantages of using Hanna pig iron.

At 20-minute intervals, C.W.C. checks metal analyses with a direct reading spectrometer.

THE HANNA FURNACE CORPORATION

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CWC

A few of the 50 million camshafts produced by Campbell, Wyant and Cannon Foundry Company.

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modern castings